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Summary for public release

Executive Summary

The DAN2203 Limited Water Decision Support project (LWDS) assessed the use of partial irrigation within the Australian cotton industry. The project sought to identify the extent and methods used that maximise the returns on water resources. It investigated the challenges for sustainable water management in the face of increasing production and business risks due to unpredictable rainfall and a variable water supply.

The scope of the technical report includes an assessment of partial irrigation practices where the crop's evapotranspiration demand is not fully met with irrigation water. It provides an analysis of strategies employed by growers to effectively manage limited water resources and it discusses strategies used to maximise bales per megalitre or gross margin (\$) per megalitre rather than bales per hectare.

The Australian cotton industry is confronted with the dual challenge of enhancing production and profitability while managing finite water resources. The unpredictability of water supply, exacerbated by climate change, poses significant risks to both growers and the industry. Partial irrigation is a practice adopted most commonly in response to low water availability such as drought. It can also be adopted by growers to maximise returns from available water.

Over the last 30 years, growers have adopted key strategies to manage irrigation water in periods with low availability. These strategies include water budgeting, strategic water application, and agronomic management such as field and row configuration, variety selection, and fertiliser management. Whilst there is evidence that water productivity can be improved by reducing the water applied per hectare without significant yield penalty, results are confounded by water use efficiency measures, the variation in the volume of water

applied and row spacings. Additionally, there is little consistency in the terminology used to describe irrigation tactics to maximise water productivity.

In conclusion, partial irrigation is currently a minor subset of irrigated cotton systems that is mostly used by growers when water supply is reduced. The practice varies between growers depending on their farm and situation. Growers and their advisers may prefer to do what they are familiar with and know to do well (i.e., full irrigation). This may seem like a less risky or stressful decision, and avoid the extra complexity, decision making and risk of partial irrigation. The decision is to grow less area with more water, or plant a larger area and cut out area if there is insufficient water.

Objectives

- **Objective 1**: Conduct a literature review to analyse the use of partial irrigation practices and their effects on water productivity.
- Objective 2: To identify innovative practices that cotton growers use to maximise water productivity in limited water scenarios and identify opportunities and constraints.
- Objective 3: To explore how growers manage the complexity of farm management decisions that influence water productivity in limited water scenarios.

Background

In a time where water availability is an increasing concern, the agricultural sector faces significant challenges. As the largest consumer of freshwater resources, agriculture must adapt to ensure ongoing food and fibre production while also addressing global challenges such as a growing population, increased pollution, and climate variability. The cotton industry operates within this complex framework which drives the need for innovative irrigation practices to maximise yield per megalitre.

Water is often the most limiting factor in irrigation systems, making efficient irrigation and rainfall management crucial. Cotton irrigators must carefully plan their water use to mitigate the risks associated with unpredictable weather patterns and maximise crop yield with the available water.

Agricultural water use is closely linked with soil conditions, weather patterns, land use, and the allocation of available water resources for irrigation. Farmers need to balance risk with opportunities to capture and use rainfall for crops to complement irrigation practices.

The production of irrigated cotton requires significant investment in land, water, and infrastructure. As pressure on water supplies increases, so will resource competition, placing a greater focus on water productivity. If this is combined with lower cotton prices and higher variable costs, it will likely increase the required marginal return on the water used. To achieve sustainable agriculture, it is crucial to thoroughly discuss efficient water use and water productivity, considering their socioeconomic implications.

A key focus of this project is the decisions cotton growers make to maximise water productivity by increasing yield from the megalitres consumed. When water is the limiting resource, the objective of irrigation should be to maximise bales per megalitre (bales/ML) or gross margin per megalitre (GM/ML).

Research activities

The DAN2203 CRDC Limited Water Decision Support project (LWDS) investigated the strategies employed by cotton growers in Australia to manage water resources under conditions of limited water availability.

In an irrigated system, partial irrigation is a broad term where plant water demands are not fully met by the supply of irrigation water. In these scenarios the primary objective is to maximise bales per megalitre or gross margin (\$) per megalitre. To understand these strategies the project addressed three areas using key research questions:

- 1. Farm management practice: What farm management practices or tactics have been investigated to improve water productivity in partially irrigated cotton systems, where are they used, and what are the gaps in knowledge?
- 2. Innovative practices: What are the innovative practices cotton growers use to maximise water productivity in limited water scenarios and what are the opportunities and constraints in applying these strategies?
- 3. Complexity of farm management: How do growers manage the complexity of farm management decisions that influence productivity in limited water scenarios?

The report provides a comprehensive exploration of partial irrigation practices and strategies employed by Australian cotton growers. The findings of this project are important for developing sustainable water management strategies in cotton farming, which can lead to improved water use efficiency and crop productivity. This is especially important in the event of a sustained reduction in allocated water and the need for agriculture to adapt to changing environmental conditions.

Milestone 1 - Literature Review: Analysis of partial irrigation practices and their effects on water productivity.

This research project conducted a thorough desktop study to evaluate farm management practices aimed at enhancing water productivity in partially irrigated cotton systems. The literature review identifies key on farm management practices and research gaps that drive water productivity in these systems.

Water is a limited resource in Australian cotton systems, and irrigation is essential to protect the yield potential and fibre quality. The challenges for both the growers and the industry include water scarcity and associated risks from climate change which have encouraged innovation of partial irrigation systems.

Partial irrigation can be viewed as a subset of an irrigation production system where the full crop evapotranspiration demand is not met by irrigation water. Growers can choose, or be forced by circumstances such as drought, to partially irrigate. In Australia, it is mainly the later when water is limited.

To date, there is no standard partial irrigation practice adopted by growers. Growers mix and match strategies to meet their farming conditions. This makes it more challenging to understand the decision-making process each grower uses when deciding to adopt partial irrigation. Despite the lack of standard practice, key processes growers have taken in the last 30 years partial irrigation include water budgeting; strategic application of available water; adaptable sowing,

agronomic management (row configuration, variety selection, fertiliser management). The overarching process is the ongoing assessment of seasonal and climatic risks and forecasting.

The low adoption of partial irrigation may be caused by the limited information from RD&E. To raise the profile of partial irrigation, there is a need for more information about the practice, its productivity, and the economic benefits. The provision of simple and standard partial irrigation guidelines may assist growers to understand and make the shift.

The following recommendations are put forward to the industry to foster continuous improvement in productivity, sustainability, and economic returns:

- Evaluate the role of partial irrigation in water productivity and water sustainability.
- Report yield and water use data on cotton production systems that use partial irrigation.
- Report water productivity from partial irrigation cotton in the water productivity benchmarking program.
- Investigate the key drivers and processes growers use to make the decision to partially irrigate.
- Promote partial irrigation as a best management practice to address water scarcity.
- Include partial irrigation as a specific technology in the cotton advisory resources.

Milestone 2 - Use case studies to compare examples of partial irrigation practice by cotton growers with the findings from literature, providing insights into where and why partial irrigation is used in Australian cotton farms.

The project aimed to identify current farm practices in limited water and partial irrigation scenarios, and better understand water management decision. This was achieved in two parts, case studies and using a Systems Thinking approach.

Six case studies investigated and outlined different approaches to partial irrigation or limited water strategies within their cotton systems. The findings offer valuable insights for other growers and stakeholders, as they highlight diverse approaches to achieving sustainable and water-efficient agricultural practices. A summary of each case can be found in the submitted Technical Report.

Systems Thinking Analysis

Through the case studies interviews, other factors were found to influence water management in cotton systems. These additional constraints influence how water is allocated annually on farm prior to establishing the yearly water budget. These encompass strategic decisions such as:

- navigating limitations in labour availability and machinery,
- considering lifestyle preferences, including accounting for the farmer's age,
- risk management, and
- balancing interest rates and financial obligations (for examples, where growers utilise water to grow crops to

generate cashflow and meet financial obligations in the current season).

A pilot study using Systems Thinking was conducted to explore these constraints and map decision-making processes. This approach, involved interviews with cotton growers, revealing that the water decision process considers of various business constraints rather than water availability alone.

Labour availability is a common constraint on farm businesses and influences farm management decisions, including irrigation practices. The pilot study combined responses from three cotton farmers and one cotton industry expert to map the complexity of farm systems, focusing on how labour influences water delivery and application to cotton crops.

Systems thinking was used as a tool to understand the interdependencies and connections of business, economic, and water decisions within the farm system. This holistic approach provided deeper insights deeper insights into on farm water management. A report with explaining the findings was written and is submitted as part of the research findings and supplied as an output for this project. (Labour influences on the application of irrigation water: A pilot study using a Systems Thinking model. (DPIRD PUB24/516))

Milestone 3 - Decision process: Using tools to show how different actions, decisions, and strategies affect water productivity.

This study involved creating a decision tree to understand how cotton growers make water management decisions, particularly when there is a reduction in available water. The goal was to identify the choices growers make under these conditions and track their outcomes to identify knowledge gaps.

Numerous decisions determine the area of cotton to be planted, which can be both implicit and explicit. Growers often make heuristic decisions based on rules of thumb or experience, while other decisions are more deliberate and informed. Within this context, practice refers to the specific techniques and methods farmers use regularly to manage water efficiently, such as drip irrigation and scheduling irrigation to improve water use efficiency. These practices ensure that available water supports cotton growth effectively.

Above this are strategies, the broader planning and decision-making processes to optimise water use over the entire growing season or across multiple seasons. This might include practising crop rotations to improve soil structure and moisture retention, using wider row configurations, and planning irrigation schedules based on weather forecasts. These strategies help farmers make long-term decisions that maximise water efficiency and crop yield.

Understanding that practices are the tactical, often day-to-day actions taken to manage water use, while strategies are the overarching plans designed, for example, to optimise water use throughout the growing season, helps clarify the complexity of water management decisions. Several limited water strategies were outlined in the Technical Report, along with associated tools and practices and a list of variables than can influence the way a strategy is implemented.

The decision tree incorporates evapotranspiration outcomes and irrigation strategies and was developed from literature. A variety of

terminology is used to describe partial irrigation and 'limited water' practices within the Australian cotton industry. These terms are often used inconsistently. The decision tree submitted with this project illustrates the relationships and differences between these commonly used terms. The decision tree highlights the complexity of decision making, and the systems that sit behind the use of WUE and water productivity metrics.

Three key decisions that determine partial irrigation were identified: the water budget, the irrigation strategy (the level of crop ETc met by irrigation), and row spacings. Further details including the decision trees are available in the Technical Report submitted for this project.

Outputs

The following documents have been developed as outputs for DAN2203.

- Literature Review Key practices and research gaps of onfarm management practices that drive water productivity in partially irrigated cotton systems (PUB23/1228)
- Systems Thinking Report including Causal Loop Diagrams Labour influences on the application of irrigation water: A pilot study using a Systems Thinking approach (PUB24/516)
- Technical Report including the Partial Irrigation Decision Tree (PUB24/786)
- Four, steering committee updates and presentations
- Four, six monthly progress reports.
- Final Report (PUB24/759)
- Presentations to MDBA to Executive and Board Members, and Project Officers.

The following case studies have been completed as NSW DPIRD Primefacts and are currently undergoing final editorial review prior to publication.

- Case Study 1 A grower's experience using a low pressure drip irrigation system (PUB23/1224)
- Case Study 2 A grower's experience using winter cover crops to build soil moisture for rainfed cotton in the Upper Namoi (PUB23/1230)

Undergoing internal NSW DPIRD review

- Case Study 3 A grower's experience doing more with what we have; changing practice and adapting to water uncertainty (PUB24/835)
- Case Study 4 A grower's experience implement 1.5 m cotton rows and 3 m furrows (PUB24/735)
- Case Study 5 A grower's experience icing the cotton-cropcake, budgeting for partial irrigations (PUB24/742)
- Case Study 6 A grower's experience understanding the implications of different irrigations strategies (PUB24/836)

Impacts

This project investigated how partial irrigation practices, which involve applying less water than required to fully satisfy crop water demands (evapotranspiration), are used in the Australian cotton industry.

Water is often described as limited, but this is a subjective term. In the context of cotton production, it should refer to the gap between available supply and the crop water demand necessary to achieve production goals. Full irrigation involves applying water to fully satisfy crop water demand.

When water supply is low, growers will commonly plant a smaller area and fully irrigate solid cotton on 1 m rows. This helps manage risk by ensuring there is enough water available to protect crop yield potential. Some, but not all, growers will plant an additional area using wider row spacings to maximise the cotton area and capitalise on potential in-crop rainfall.

In Australia, partially irrigated cotton is a minor subset of irrigated cotton. The area developed for partial irrigation in Australia is estimated to be 2-3 percent of the cotton farm. It is predominantly utilised by growers when water availability is limited or unpredictable. The practice has largely been driven by low water availability, such as periods of drought or low water allocation. While a small number of Australian cotton growers opt to use partial irrigation by choice, the exact number is unknown.

There is no standard partial irrigation practice, and there is confusion around the terms for irrigation practices that do not fully meet crop evapotranspiration requirements. This includes variations in the amount of water applied and the row spacings used.

Although technology has advanced, the core practices that growers use to manage reduced water allocation (such as during droughts) have remained largely consistent over the past 30 years. These practices have been integral to optimising water use and maintaining crop productivity and include:

- Water budgeting: based on water supply, stored soil moisture, and seasonal outlook to determine the area to be planted, including decisions about fields and row configuration.
- Strategic irrigation: applying available water during critical growth stages to minimise yield and fibre quality penalties.
- Agronomic and farming systems: considering soil water availability at sowing, variety selection, fertiliser use, crop rotations, soil water conversation practices, field selection, and strategies to minimise water losses.

These practices ensure that water resources are used efficiently, and crop productivity is maintained even under challenging water supply conditions.

The case studies reveal growers are using partial irrigation in various ways for different reasons which include:

- Considering multiple factors: water is not the only driver; complexity such as labour, lifestyle, and machinery may also play significant roles.
- Optimising water use: water is a major factor in determining the cotton area, and some growers are finding ways to grow more cotton from available water supplies.

- Growing cotton on wider rows: assisting to ingrate rainfed and irrigated cotton machinery use.
- Extending planted area: by using partial irrigation to increase the area planted to cotton when water is plentiful.
- Strategic irrigation: applying irrigation water strategically to match the crop's growth stages, thereby minimising yield and quality losses during periods of low water supply.
- Combining strategies: employing various strategies over a season to optimise outcomes.

There appears to be insufficient economic analysis to determine the most profitable strategies when comparing maximum yield per ha to maximum yield from the scarcest resource – irrigation water. The available gross margins for double skip semi-irrigated cotton are limited in their definition of row configuration and the amount of water applied.

The project has demonstrated the complexity growers face when making water management decisions. The desire to make the most of available water drives partial irrigation practices.

Whilst it is easy to discuss components of partial irrigation practice, these systems are complex and inter-connected. Other constraints such as labour, financial obligations, personal and business goals also influence the adoption of these practices. The objectives of growers and the industry are not always the same. Growers need to manage risk on a year-to-year basis to secure their business. Industry needs to demonstrate they are good stewardships of the water resource and produce the maximum amount of cotton from each megalitre of water.

Key publications

Please note the full list of potential project publications in the Outputs section, including the Literature Review, status of all six case studies Systems Thinking and Technical Reports.