Impact assessment of the investment:

Improving citrus quality with regulated deficit irrigation (CT17000)

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Hort Innovation

Previous page image courtesy of NSW DPI 2021.

Disclaimer:

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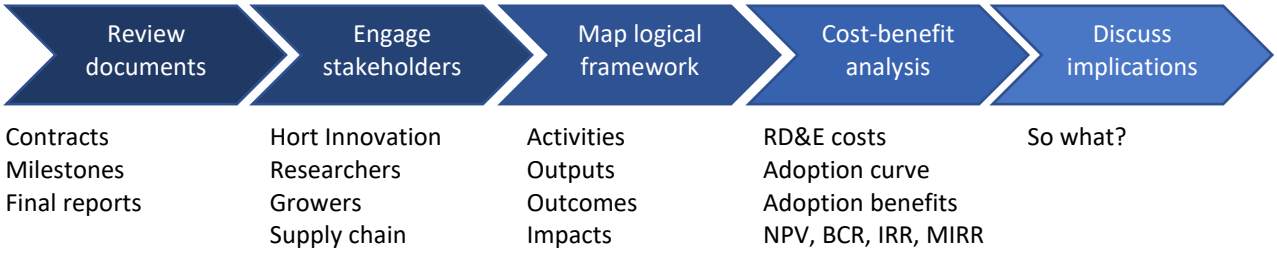
Executive summary

What the report is about

Ag Econ conducted independent analysis determine the economic, social, and environmental impact resulting from delivery of the citrus project *Improving citrus quality with regulated deficit irrigation (CT17000)*. The project was funded by Hort Innovation over the period December 2017 to September 2022 using the citrus research and development levy and contributions from the Australian Government. The project was delivered by NSW Department of Primary Industries (DPI).

The analysis applied a five step analytical process to understand the impact pathway and collect supporting data.



Research background

The Australian citrus industry has undergone a period of expansion in recent years, primarily through increased export demand. The majority of Australian citrus is exported across Asian markets which make up between 80-90% of total export volumes. Given that Asian markets hold a strong preference for low acid, sweet citrus fruit (primarily oranges and mandarins) improving citrus fruit quality into these markets was identified as a priority by the Australian citrus industry to improve consumer demand for Australian citrus and overall industry competitive advantage.

Regulated deficit irrigation (RDI) is a novel practice that has been shown to support improved fruit quality (sweetness) through promoting changes in tree physiology. Whilst this method has been trialed in other settings, research into the RDI technique specific to the Australian citrus industry was required in order to determine a practical method suitable for Australian production conditions.

Key findings

The nominal investment cost of $0.42 million was adjusted for inflation (ABS, 2024) and discounted (using a 5% real discount rate) to a 2023-24 present value (PV) of costs equal to $0.63 million.

The analysis conducted a detailed evaluation of the CT17000 impact pathway through a logical framework, and a review of the available data supported by consultation with stakeholders to quantify the impact pathway. From this process, economic, environmental and social impacts were identified as having the potential to be realised through the research from increased demand for Australian citrus in export markets, reduced production costs and improvements to water use efficiency.

However the identified impacts could not be quantified due to an uncertain adoption pathway for industry. Discussion with stakeholders identified the requirement for additional research to be undertaken across a broader range of citrus production systems before industry-wide adoption could be expected to occur. As this additional research has not been scoped or committed the analysis determined that while a range of impacts could potentially be supported, CT17000 is too early in the adoption pathway for adoption and impact to be realised.

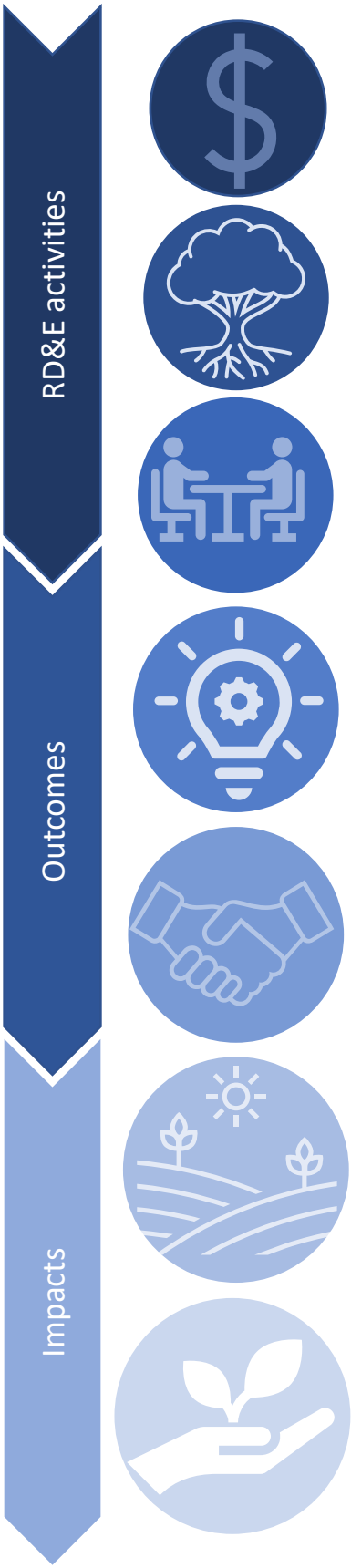
The key findings of the CT17000 impact assessment are summarized in Figure 1 below.

Keywords

Impact assessment, cost-benefit analysis, citrus, regulated deficit irrigation, fruit quality, fruit size, consumer demand, M7, Lanes Late, Afourer

Figure 1. Summary of impact assessment findings

CT17000 Citrus regulated deficit irrigation



Total RD&E costs:

- $0.42 million (nominal value)
- 100% R&D levy and Government matching.

Research activities:

- Trial establishment and delivery at research site focusing on six reduced irrigation treatments across four seasons.
- Testing and monitoring tree growth and fruit quality throughout trial period.
- Sensory evaluation of harvested fruit.
- Test drone technology to detect canopy temperatures and water stress response.
- Storage trials to assess impact on fruit quality.

Extension activities:

- 5 x field days delivered on the trial site in Dareton, NSW.
- 2 x conference presentations.
- 1 x fact sheet provided at field days.
- 3 x communication articles

Outcomes:

- Improved knowledge of the RDI method for increasing internal citrus fruit quality.
- Improved knowledge of the timing of RDI and the associated interaction between variety, irrigation rate and rootstock support grower capacity to adopt the technique
- New knowledge of the potential for RDI to increase water use efficiency.

Industry adoption:

- Industry-wide adoption is yet to occur given the requirement for further research to refine practical application of the technique across a wider range of production settings.

Industry economic impacts:

- Increased industry revenue from growth in export market value and reduced production costs from improved water use efficiency.

Environmental impacts:

- Increased water use efficiency reduces water footprint of citrus production.

Social impacts:

- Community spillover benefits from a profitable citrus industry.

Total attributable benefits and impact:

- Present value (PV @ 5% discount) RD&E costs of $0.63 million.
- A quantitative impact assessment was not performed due to RDI practices not yet being adopted throughout industry given the need for ongoing research to refine the technique for broader production settings.

Introduction

Evaluating the impacts of levy investments is important to demonstrate the economic, social and environmental benefits realised through investment to levy payers, Government and other industry stakeholders. Understanding impact is also an important step to inform the ongoing investment agenda.

Reflecting its commitment to continuous improvement in the delivery of levy funded research, development and extension (RD&E), Hort Innovation required a series of impact assessments to be carried out annually on a representative sample of investments of its RD&E portfolio. Commencing with MT18011 in 2017-18, the impact assessment program consisted of an annual impact assessment of up to 15 randomly selected Hort Innovation RD&E investments (projects) each year. In line with this ongoing program, Ag Econ was commissioned to deliver the *Horticulture Impact Assessment Program 2020-21 to 2022-23* (MT21015).

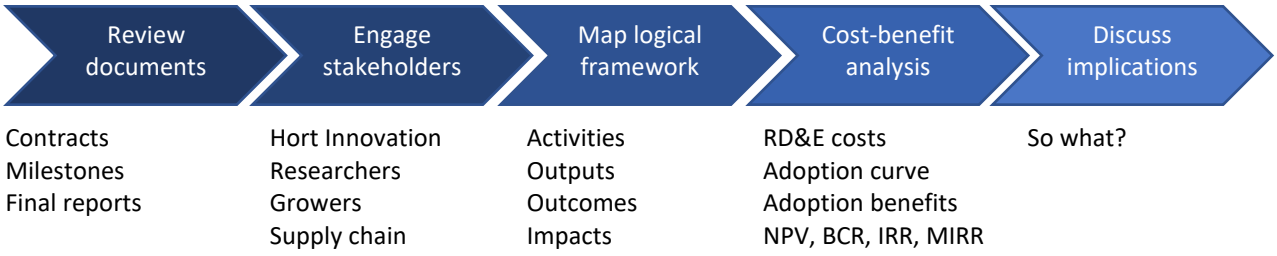
Improving citrus quality with regulated deficit irrigation *(CT17000)* was randomly selected in the 2022-23 sample. This report presents the analysis and findings of the project impact assessment.

The report structure starts with the general method of analysis used, followed by the RD&E background and an outline of the impact pathway in a logical framework, then describes the approach used to quantify the identified costs and benefits including any data gaps and limitations to the analysis, presents the results including from the sensitivity analysis, and finally discusses any implications for stakeholders.

General method

The impact assessment built on the impact assessment guidelines of the CRRDC (CRRDC, 2018) and included both qualitative and quantitative analysis. The general method that informed the impact assessment approach is as follows:

1. Review project documentation including project plan, milestone reports, outputs and final report.
2. Discuss the project delivery, adoption and benefits with the Hort Innovation project manager, project researcher/consultant, growers and other relevant stakeholders (see *Stakeholder consultation*).
3. Through a logical framework, qualitatively map the project's impact pathway, including activities, outputs, and outcomes to identify the principal economic, environmental, and social impacts realised through the project
4. Collect available data to quantify the impact pathway and estimate the attributable impacts using cost-benefit analysis (over a maximum 30 years with a 5% discount rate), and then sensitivity test the results to changes in key parameters.
5. Discuss the implications for stakeholders.



The analysis identified and quantified (where possible) the direct and spillover impacts arising from the RD&E. The results did not incorporate the distributional effect of changes to economic equilibrium (supply and demand relationships) which was beyond the scope of the MT21015 impact assessment program. A more detailed discussion of the method can be found in the *MT21015 2021-22 Summary Report* on Hort Innovation project page Horticulture Impact Assessment Program 2020/21 to 2022/23 (MT21015).

Project background

The citrus industry has experienced strong export growth especially in Asian markets in recent years, supported by expanding market access, free trade agreements and export development activities focused on supporting grower capabilities and building the reputation for Australian citrus. Over the 10 years to 2022/23 the total volume of citrus exports has increased by 38% (64,000 tonnes), and total value has increased by 135% ($253 million) indicating strong market demand given the value of citrus exports is growing faster than the total volume supplied (Hort Innovation 2024). Despite the growth in exports and strong demand, Australian exports comprise a relatively small share of citrus into Asian markets, given large import volumes

of citrus from other southern hemisphere producers.

To ensure that ongoing demand for Australian citrus is sustained into the future, the industry has sought to develop growing practices that contribute to improvements in fruit quality. Industry commitment to the production of quality fruit is demonstrated through the development of minimum maturity standards to ensure that fruit is of an acceptable quality for consumers (CT12004, CT15013) in order to support satisfaction, reputation and sustained demand. By way of supporting growers to produce high quality fruit, a wide range of investment has been initiated to develop growing practices and supply chain capability (e.g. CT09014[1], CT12023[2], CT15010[3], CT18002[4], CT22002[5]). A potential avenue for continuing to advance growing practices and quality improvements was presented through the practice of regulated deficit irrigation (RDI), which focuses on restricting water to citrus trees at key times in the seasonal growth cycle to stimulate improvement to internal fruit quality (Brix^{o} and acid %).

While the role of RDI in improving fruit quality had been demonstrated in select trials internationally, the potential suitability and associated RDI management protocol appropriate for Australian conditions was unknown. CT17000 was therefore undertaken to trial the application the RDI technique to assess the potential of the practice to improve citrus fruit quality and develop guidelines to support grower adoption. A key consideration for the research was the impact of deficit irrigation on fruit size. While fruit size is not directly associated with eating quality per se, maintaining the capacity to produce large fruit remains an attribute that contributes to market and consumer product value. Therefore developing a RDI practice that ensured growers could still achieve desired fruit size was a key consideration that underpinned the research. The research focused specifically on oranges (M7, Washington, Lane Late) and mandarins (Afourer), given that these citrus types are commonly exported and would benefit from increased fruit quality in supporting market demand.

CT17000 aligned with the Citrus Strategic Investment Plan (SIP) 2022-2026 through:

- Outcome 2: Protect the production base.

Project details

CT17000 was funded from 2017 to 2022 (Table 1).

Table 1. Project details

Project code	CT17000
Title	Improving citrus quality with regulated deficit irrigation
Research organization(s)	NSW DPI
Project leader	Tahir Khurshid
Funding period	December 2017 to September 2022
Objective	Develop a practical regulated deficit irrigation method for key citrus varieties to improve production capacity of sweeter fruit, contributing to increased export demand through improved reputation and consumer satisfaction.

Logical framework

The impact pathway linking the project's activities and outputs, and their assessed outcomes and impacts have been laid out in a logical framework (Table 2).

[1] CT09014. Early-season replacement for Imperial mandarin

[2] CT12023. Enhancing the export performance of Australian mandarins by improving flavour quality

[3] Australian Citrus Postharvest Science Program

[4] Citrus market development, market access and quality

[5] CT22002. Citrus market development and quality program

Table 2. Project logical framework detail

RD&E activities

Trial establishment and experimental design

- Trial for navel oranges (M7, Washington, Lanes Late) established at research site located in Dareton, NSW.
  - Six irrigation treatments were applied, varied over four seasons (2018, 2019, 2020, 2021)
  - Treatments were replicated over six blocks (540 trees total).
  - RDI treatments occurred over the February-April growing season.
  - Treatments were based on reduced percentages of the control irrigation schedule.
- Trial site for mandarin (Afourer) established on two grower properties in the Sunraysia region.
- Annual reference evaporation and rainfall data was collected for each experimental season.
- Install gypsum blocks, soil moisture probes and tensiometers to faciliate irrigation, soil profile and tree physiology data capture.

Trial delivery and management

- Irrigation treatments were randomly applied to the entire row within a block according to the prescribed deficit protocol (dry, 50% irrigation, 100% irrigation).
- Twice weekly readings of plant water status (tree leaf samples) using pressure chamber measurements.
- Fruit growth data collected through the growing season from randomly selected trees.
- Fruit quality and total production yield for each experimental tree was assessed at harvest.
- Fruit quality profiles (Brix°, acid %) were collected weekly.
- Drone flight to assess water stress in navel orange trees (via canopy temperature and crop water stress test index method).

Sensory evaluation trials for navel oranges

- Collection of fruit samples for sensory testing (2019, 2020).
- Recruit participants from local tertiary institution (SuniTAFE Mildura) and production businesses.
- Develop sensory questionnaire and supervise process.
- Results analysed using statistical procedures.

Storage trials

- Fruit selected and Brix° and acid values tested for up to 35 days post harvest.
- Results recorded and analysed to determine the interaction between fruit quality and storage characteristics.

RD&E outputs

- **1 x final report** on the Hort Innovation website.
- **5 x field days** delivered on the trial site in Dareton, NSW.
- **2 x conference presentations** including internationally.
- **1 x fact sheet** outlining recommended RDI practices to be provided at field days.
- **3 x communication articles:**
  - Khurshid, T. 2019. Early results for deficit irrigation trials. Australia Citrus News. August edition, pages 30-31.
  - Results are sweet (Sunraysia daily). February 2019.
  - Khurshid, T. 2020. Regulated deficit irrigation techniques enhance sweetness. CitrusConnect (March), NSW DPI.

Outcomes

The key end of project outcome for CT19000 was the development of new knowledge and recommended RDI practices to improve internal citrus quality.

- **Validation of RDI method.** Results from the RDI trials identified potential quality improvement of up to 1-1.5 brix° however a 10% reduction in fruit size for every 1° brix increase was noted.
- **Improved capacity to increase citrus fruit quality.** Recommendations on timing of RDI and the associated interaction between variety, irrigation rate and rootstock support grower capacity to adopt the technique.
- **New knowledge on practices to increase water use efficiency.** Preferred RDI protocols were demonstrated with a reduction in irrigation water requirements of 0.77ML/ha.

Impacts

Industry adoption of RDI practices has the potential to support increased consumer demand and water use efficiency, which would generate the following specific impacts:

- [Economic] Increased industry revenue from growth in export market value through increased consumer demand.
- [Economic] Reduced production costs through improved water use efficiency.
- [Socio-economic] Supporting the supply of affordable domestic citrus to Australian consumers, resulting in increased consumption and an increase in associated health and wellbeing benefits.
- [Socio-economic] Increased contribution to regional community resilience and wellbeing from more profitable citrus growers, particularly in the Sunraysia and Riverland regions (The CIE 2023, 2023).
- [Environmental] Reduced water footprint and demand through improved water use efficiency.

Project costs

The project was funded by Hort Innovation, using the citrus research and development levy and contributions from the Australian Government.

Nominal investment

The project funding period was 2018 to 2023 (Table 3). Hort Innovation overhead costs were added to the direct project cost to capture the full value of the RD&E investment

Table 3. Project nominal investment

Year end 30 June	Hort Innovation project costs ($)	Hort Innovation overheads[1] ($)	Total nominal cost ($)
2018	71,443	14,031	85,474
2019	143,074	22,547	165,621
2020	71,443	12,821	84,264
2021	0	0	0
2022	71,443	11,813	83,256
Total	**357,403**	**61,212**	**418,615**

1. The overhead and administrative costs were calculated from the Financial Operating Statement of the Citrus Fund Annual Reports, averaging 17.2% for the CT17000 funding period (2018-2022).

Present Value of investment

The nominal total investment cost of $0.42 million identified in Table 3 was adjusted for inflation (ABS, 2024) into a real investment of $0.50 million (2023-24 equivalent values). This was then further adjusted to reflect the time value of money using a real discount rate of 5% (CRRDC 2018), generating a present value (PV) of costs equal to $0.63 million (2023-24 PV).

Project impacts

The impact pathways identified in Table 2 were evaluated against available data to determine if their impact could be quantified with a suitable level of confidence.

None of the economic, environmental or social impacts identified through the logical framework process were able to be quantified due to feedback received from industry stakeholders regarding the readiness of the research findings to support wide scape industry adoption and two significant data limitations:

- the unknown interaction between increased fruit quality (Brix^{o} and acid %) and price in citrus export markets.
- the impact of the RDI practice on fruit quality across different soil types, rootstocks, tree health, crop management practices and climatic conditions beyond what was tested in the trial.

Discussions with industry stakeholders confirmed that while the RDI method was successful at demonstrating a proof of concept for increasing internal fruit quality, further research is required to understand the suitability of the practice in other growing regions over a longer period of time, and further exploring alternative methods that mitigate reductions in fruit size before growers would consider the adoption of RDI practices. Further understanding the potential for value creation in Asian export markets through the supply of higher quality (Brix, acid) fruit beyond the existing attributes and perceptions of Australian fruit in these markets is also needed to inform impact.

As a result, while CT17000 did identify the potential for RDI to increase citrus fruit quality, the RDI practice is not considered to be 'adoption ready' for mainstream commercial growers across the various citrus production regions. Further R&D on the suitability of the practice across other growing conditions, and understanding of market dynamics and value potential that through changes to internal fruit quality beyond traditional measures such as size and external appearance is required before adoption can be defined and impact pathway defined for the citrus industry through the RDI method. As there is no ongoing commitment from the citrus industry to invest in further research to develop these areas, the potential impact attributed to the contributions from CT17000 could not be valued given the research is too early in the impact pathway.

Implications and learnings

The delivery of CT17000 developed new knowledge of RDI for improving citrus quality by completing a large scale controlled field trial for three commercial navel orange varieties (M7, Washington, Lanes Late). While a trial was also delivered at a grower site for a commercial mandarin variety (Afourer), results were inconclusive following rainfall events coinciding with the intended irrigation deficit period. Across the navel trials, deficit irrigation timing, rootstock and citrus variety were all identified as having a positive impact on internal fruit quality (Brix^{o} and acid %). While fruit quality was positively impacted, the timing of water deficit was also shown to negatively impact fruit size (another important determinant of citrus value in export markets), highlighting that RDI must be only be used when supported by well-informed timing schedule. With the ongoing growth of the citrus industry being largely driven by export demand from Asian markets which have a distinct preference for sweet fruit, successful grower adoption of the RDI method has the potential to enhance the reputation of Australian citrus fruit in these markets

While CT17000 demonstrated the potential of RDI for increasing fruit quality, the interaction between related variables (e.g. soil, rootstock, variety, climate, management practices) outside of the trial site conditions remain untested. This was identified by stakeholders as a key factor limiting the extent to which the research findings can practically inform grower decision making. As RDI practice recommendations were informed exclusively through the confines of a single field trial, stakeholders commented that further research is required to develop a more practical understanding across other production regions/conditions if widescale grower adoption is to be expected. However, as no further research has been committed to further developing RDI, the current knowledge supported by CT17000 is considered too early in the impact pathway to have the potential to generate tangible industry impacts. While a range of potential impacts were identified, quantification was not possible given ongoing refinement that would occur through additional research.

To ensure future research focused on RDI practices supporting increased fruit quality can be informed by an accessible and achievable impact pathway, the provision of an 'adoption ready' tool or calculation method that can guide growers on suitable RDI practices given their operating context could be considered. The potential rate of adoption and impact will also be influenced by the value creation from supplying markets with higher quality fruit. Validating the value opportunity in export markets will also be required to identify the scale and magnitude of potential price premiums that could be realised by growers.

Stakeholder consultation

Where possible, Ag Econ sought to engage multiple stakeholders across key areas of the logical framework and impact pathway to augment existing information and data sources, and reduce any uncertainty or bias from individual stakeholders. All stakeholders were engaged through telephone or online meetings, with follow up emails as necessary. Consultation followed a semi-structured approach in line with broad topics relating to the impact pathway and associated data requirements. Table 6 outlines the stakeholders consulted as part of this impact assessment and the topics on which they were consulted.

Table 6. Stakeholder consultation by theme

Stakeholder details		Consultation topics						
Stakeholder and organisation	**Stakeholder type**	**Related research**	**Research inputs**	**Research outputs**	**Research immediate outcomes**	**Follow on research**	**Stakeholder adoption**	**Impact areas and data**
Adrian Hunt, Hort Innovation R&D Manager	RD&E process owner / manager	✓	✓	✓	✓	✓	✓	✓
Dr Tahir Khurshid, NSW DPI Research Physiologist	RD&E practitioner	✓	✓	✓	✓	✓		✓
Dean Morris, Moricom Orchards	RD&E beneficiary and levy payer			✓	✓		✓	✓

Glossary of economic terms

Benefit-cost ratio (BCR)	The ratio of the present value of investment benefits to the present value of investment costs.
Cost-benefit analysis (CBA)	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Direct Effects	Impacts generated for the funding industry as a result of adoption of the RD&E outputs and recommendations, typically farm level outcomes relating to productivity and risk.
Discounting and Present Values	The process of relating the costs and benefits of an investment to a base year to reflect the time value of money or opportunity cost of RD&E investment. The analysis applies a real discount rate of 5% in line with CRRDC Guidelines (CRRDC 2018) with results sensitivity tested at discount rates of 2.5% and 7.5%.
Economic Equilibrium	Due to a market's underlying supply and demand curves, changes in supply will have an impact on price and vice-versa. The Economic Equilibrium is the point at which market supply and price are balanced. Estimating the magnitude of market response to changes in supply or demand is a complex and demanding task that is considered beyond the scope of most CRRDC Impact Assessments (CRRDC 2018).
Gross Margin (GM)	The difference between revenue and cost of goods sold, applied on a per hectare basis and excluding fixed or overhead costs such as labour and interest payments.
Internal rate of return (IRR)	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Modified internal rate of return (MIRR)	The internal rate of return of an investment that is modified so that the cash inflows generated from an investment are re-invested at the rate of the cost of capital (in this case the discount rate).
Net present value (NPV)	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Nominal and real values	Nominal values reflect the actual values in a given year (e.g. contracted RD&E expenses). These are converted to real (inflation adjusted) values to make them comparable across time.
Spillover Effects	Impacts generated for stakeholders who did not fund the RD&E, including other agricultural industries, consumers, communities, and the environment.

Abbreviations

CRRDC Council of Rural Research and Development Corporations

CSIRO The Commonwealth Scientific and Industrial Research Organisation

NSW DPI Department of Primary Industries RD&E Research, Development and Extension

RDI Regulated deficit irrigation

SIP Strategic Investment Plan

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Ends.