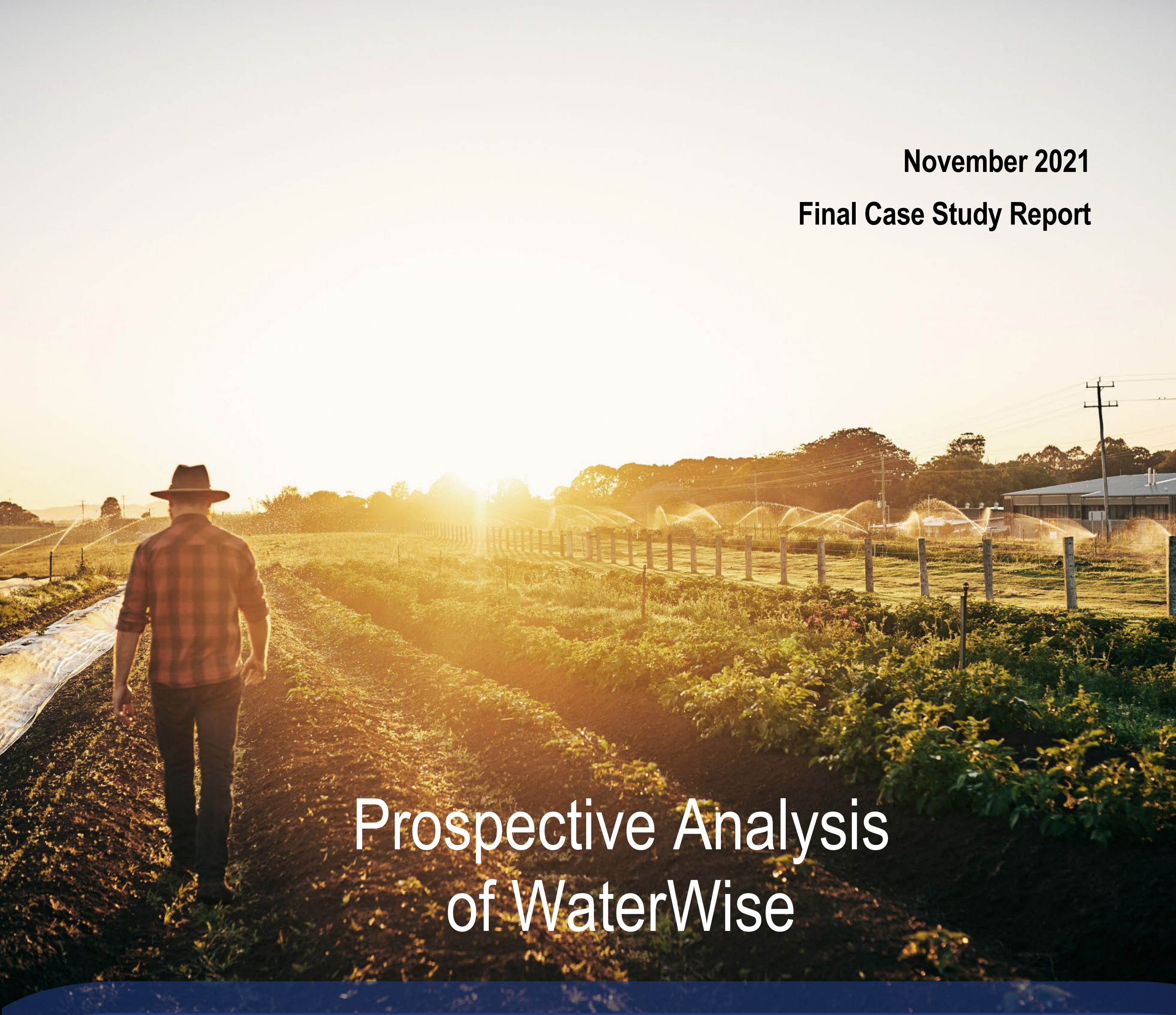


November 2021

Final Case Study Report

Prospective Analysis of WaterWise

Prepared for

Anne-Maree Dowd Planning, Performance, and Impact
CSIRO
Pullenvale QLD 4069
Australia

Prepared by

Jeffrey Petrusa
Emily Decker
Avery Tilley
Alan O'Connor
RTI International
3040 E Cornwallis Road
Research Triangle Park NC 27709
USA

RTI Project Number 0218100

Contents

Figures

Tables

Executive Summary

WaterWise is a digital agricultural water-use efficiency system that provides plant-based monitoring of crop water stress to inform irrigation decision-making. Using in-field canopy temperature sensors, it employs machine learning, advanced data analytics, spatial sensing systems, and weather forecasting to predict future water requirements for high-value crops.

The WaterWise initiative aims to enhance the ability of Australian farmers to make decisions regarding irrigation timing. Scheduling irrigation at the correct time is critical for maximising yield, quality, and water-use efficiency in agriculture. By providing farmers with real-time information to accurately plan crop irrigation, WaterWise can reduce the water footprint of high-value crops while maximising their yield.

The technology has the potential to benefit the Australian agriculture sector, with the most notable impact on the most water-intensive agricultural commodities and other farming operations that rely on flood irrigation practices. The intended end users of the technology are primarily individual irrigation farmers, although agribusiness will have a role in deploying the technology and maintaining the systems. Examples of the potential benefits of its adoption include:

- Improved water use efficiency will result in water savings that could benefit industries by increasing crop area or yield, thus increasing revenues.
- Increased confidence in irrigation decision-making can enable growers to minimise risk and seasonal variability, as well as become more resilient to climate-related hazards and extreme events.
- Optimal use of water can make crops more environmentally sustainable and reduce the water and carbon footprint of the agriculture sector.
- WaterWise may generate new opportunities to expand the breadth of services provided by the agribusiness sector.
- Direct co-benefits of greenhouse gas emissions reductions can be achieved from reduced energy consumption for irrigation pumping due to decreased water use.
- Indirect co-benefits are likely for other sectors from the reduction in agricultural water use and demand.
- Demonstration effects may be generated for other cropping systems and commodities, which could benefit from this or similar technologies.

The WaterWise initiative consisted of a multi-year research study funded by the Commonwealth Scientific and Industrial Research Organisation’s (CSIRO’s) Digiscape Future Science Platform with the stated purpose of increasing the planted area, yield, and quality of water-constrained irrigated industries. CSIRO invested a total of $5.6 million (nominal terms) over a 5-year period starting in fiscal year (FY) 2016–17 and concluding in FY2020–21. This program builds on earlier research co-funded by CSIRO

and the Cotton Research and Development Corporation (CRDC).[1] The CSIRO WaterWise development team was led by Rose Roche, PhD. The first commercial partner for WaterWise is Goanna Ag, an Australian AgTech company that produces agricultural sensing systems for water-use efficiency.

Currently, WaterWise is still in commercial development. As such, this case study report presents a case study that evaluated three adoption scenarios (low, medium, and high) of the technology for four high-value crops (cotton, sugarcane, tomatoes, and almonds). Each scenario results in different economic impacts because of each scenario's projected reduction in costs and increase in yields.

Under the low scenario, it was assumed that a 30% penetration rate is achieved, 50% under the medium scenario, and 70% under the high scenario. Approximately 70% of farms use some type of irrigation management system, which we believe is a conservative upper bound for our scenarios. Realistically, given the range of expected water savings benefits, a high penetration is plausible.

Our team found that WaterWise has the potential to provide between $48 million and $769 million in economic impacts (present value terms, 2020, 7% discount rate) accruing to Australian agricultural producers between 2021 and 2030 (Figure ES.1).[2] Under the medium scenario, we estimated the present value of impacts to range between $180 and $346 million.

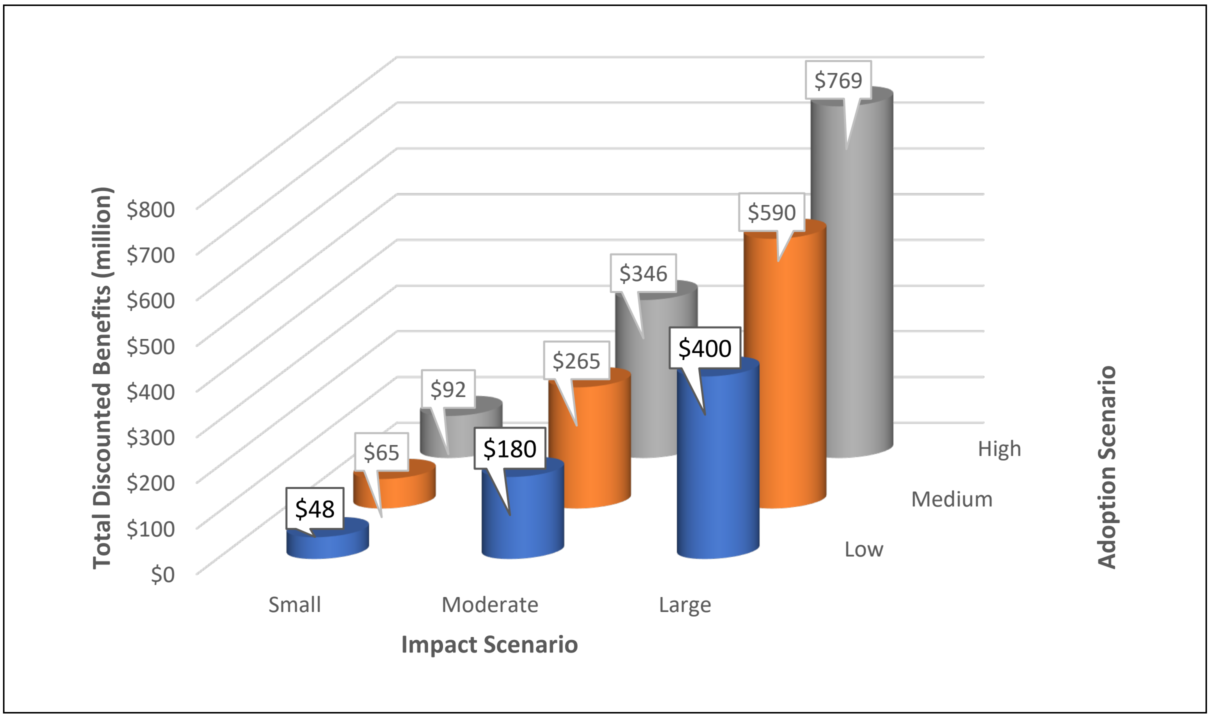
The associated water savings driving the economic impact results ranged between 179 and 2,476 thousand megalitres over the 10-year period (Figure ES.2). These results are limited to only four of the most water-intensive agricultural commodities—cotton, sugarcane, tomatoes, and almonds. Benefits quantified in this study include water and energy savings and increased yields where applicable. The largest proportion of benefits are associated with operational cost savings through decreased water usage and corresponding reductions in energy consumption for irrigation pumps. Additional benefits are expected to come in the form of increased yields on existing harvested areas for each commodity.

From a social perspective, the largest proportion of benefits are expected to come from on-farm use, which would likely result in improved water efficiency in irrigation practices and therefore improved yields. In addition, we estimated that WaterWise under the various adoption and impact scenarios has the potential to reduce CO_2 emissions ranging between 111 and 1,544 kilotonnes. These reductions are equivalent to removing approximately 336,000 passenger vehicles from the road for 1 year or avoiding 186,000 households' annual energy consumption.

[1] This analysis only considers the investment made by CSIRO for the WaterWise program, it does not include earlier investments made jointly by CRDC and CSIRO.

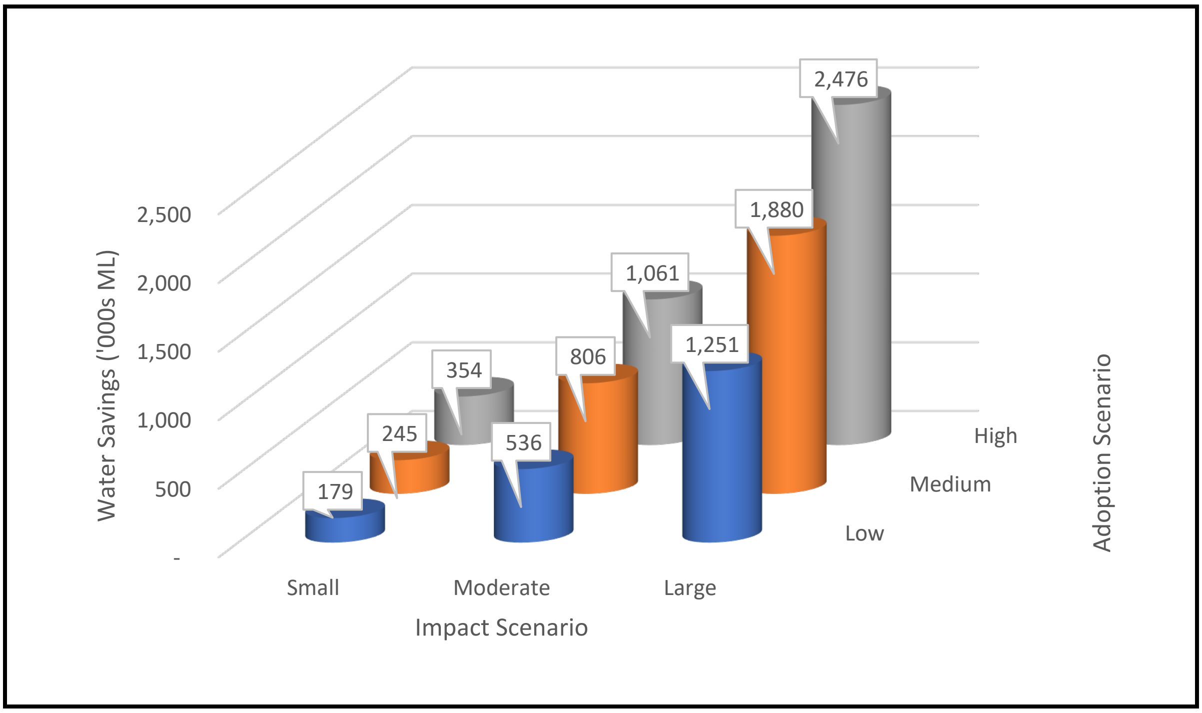
[2] Each scenario result is the present value of future benefits from 2021 through 2030, assuming WaterWise is deployed commercially in 2021. We employed a 7% real social discount rate, per CSIRO conventions. The dollar year and the base year for discounting are both 2020.

Figure ES.1. Estimated Total Present Value of Benefits from WaterWise Between 2021 and 2030 Across a Range of Adoption and Impact Scenarios



Note: Dollar values are in millions of 2020 dollars, discounted to 2020 using a 7% real social discount rate.

Figure ES.2. Estimated Total Water Savings (ML) from WaterWise Between 2021 and 2030 Across a Range of Adoption and Impact Scenarios



1. Introduction and Background

WaterWise is a digital agricultural water-use efficiency system that allows plants to communicate water needs to farmers. The technology relies on a network of sensors to provide plant-based monitoring of crop water stress to inform irrigation decision-making, thereby increasing yields and the quality of crops. WaterWise seeks to reduce the water footprint of growers in Australia by providing digital strategies so they can confidently apply irrigation water at the right time.

Using data collected on site and presented in a web-based application, WaterWise allows growers to time irrigation to keep crops in an optimum temperature range. The application relies on on-the-ground sensors, weather forecasts, and advanced analytics to present real-time data to growers. These data allow growers to see water stress to date and a prediction of their crops' future stress, leading to better irrigation practices for high-value crops.

The development of WaterWise started in response to irrigation practices in Australia and a vision for increased water conservation. For most of human history, irrigation management relied on growers to make decisions on when to water their crops, but crops were often over- or underwatered. In a survey of Australian irrigators, a majority use a subjective process to decide when to irrigate, as well as calendar or rotational scheduling with past knowledge and observation (ABS, 2015).

Irrigation timing is crucial to minimise negative effects on yield and quality. When making these decisions, managers rely on experience and not data. These decisions have led to water inefficiencies in Australia that have affected communities and growers. WaterWise allows growers to make informed irrigation choices with real-time data to provide the best timing for irrigation based on the crop, soil type, regional climate, system capacity, water availability, and risk. WaterWise achieves this through:

- identifying biological targets, such as canopy temperature, to measure plant stress;
- using data analytics to incorporate this knowledge with in-field sensing and weather forecasts; and
- developing strategies that use this information to build a precision irrigation decision-making toolbox.

WaterWise aims to reduce water use in high-value crops such as cotton, sugarcane, tomatoes, and almonds. Australia is a key producer and exporter of cotton, on average, representing 10% to 13% of world exports from Australia's 1,500 cotton farms (U.S. Department of Agriculture [USDA], 2021). Of the 1,500 cotton growers, approximately 30% are not using any objective irrigation scheduling technology. Most of the cotton growers, around 70%, use soil moisture probes. These farms rely on outside sources and water reservoirs for irrigation, which can be greatly affected by unforeseen droughts (USDA, 2021). Other high-value crops also rely heavily on water reservoirs. WaterWise allows growers to conserve water and increase yields by irrigating the correct amount needed at the correct time for the crop, decreasing growers' overall water footprint.

Additionally, water savings through improved water use efficiency provide some additional environmental co-benefits, for example, a reduction in greenhouse gas emissions resulting from reduced energy consumption at irrigation pumps. There may also be indirect impacts of increased water availability benefiting local communities. Additional community benefits could be created through improved irrigation industry performance (value), improving the regional economy and resulting in the creation of additional jobs and economic activity in rural areas. Strategies to minimise risk and variability may also provide stability to communities exposed to increasingly variable and changing climates.

This report quantifies the potential impacts stemming from WaterWise. It describes the technology, leverages learnings from the scientific and economic literatures, and describes the potential economic benefits from various use cases at varying degrees of adoption and impact. The overall goal is to provide a reasonable assessment of how WaterWise may generate social value for Australians over the 10-year period from 2021 through 2030.

1.1 Digiscape Future Science Platform

WaterWise's development was supported by the Future Science Platform initiative. Future Science Platforms (FSPs) are investments in science that underpin innovation and have the potential to help reinvent and create new industries for Australia. FSPs are designed to grow the capability of a new generation of researchers and allow Australia to attract the best students and experts.

Digiscape refers specifically to the digital agriculture FSP. According to CSIRO, Digiscape is about harnessing the digital revolution for Australian farmers and land managers. It endeavours to solve multiple real-life knowledge shortfalls in the land sector simultaneously by building a common big data infrastructure to support next generation decision-making and transform agricultural industries and environmental action.

1.2 The Science Behind WaterWise

Historically, Australian farmers have made critical decisions regarding irrigation management based on experience and personal judgment rather than definitive data. This subjective method of decision-making has resulted in significant variability in yield and water use efficiency outcomes among producers in the agricultural sector. A lack of accurate decision-making in irrigation scheduling can result in negative outcomes for the yield, quality, and water efficiency of high-value crops.

Many factors affect irrigation decisions, including differences in soil type, regional climate, water availability, system capacity, attitude to risk, and amount of data collected. When these factors become unpredictable, such as when an extreme weather event occurs, it becomes difficult to accurately time crop irrigation based on experience alone. This uncertainty can lead to excessive water use, reduced yield and productivity, and loss in revenue.

CSIRO developed the WaterWise initiative to provide a standardised, evidence-based method of decision-making for irrigation scheduling. WaterWise was developed as a toolbox with two key components: sensing and data analytics. By using in-field sensors and single-location thermal cameras, the system monitors and measures the canopy temperature of crops over 15-minute increments. Canopy temperature is strongly related to soil moisture availability, making it an accurate indicator of crop water stress status. The data are then sent to CSIRO's sensor data infrastructure, Senaps-LAND, which combines it with a weather forecast based on local climate data. Machine learning allows CSIRO to apply an algorithm to predict the crop's irrigation requirements for the next 7 days.

WaterWise represents a breakthrough in precision agriculture resulting from improvements in wireless sensor technology and advanced data analytics. These technological advances have enabled the use of plant-based sensing technologies to continuously monitor crops and soils and thus provide accurate measures and predictions of crop-water stress status. Water stress is assessed through a detailed understanding of crop physiology, including canopy leaf temperature and photosynthetic performance. By developing digital strategies to identify and quantify crop water stress, farmers can then assess this information to make better informed irrigation management decisions.

WaterWise stands out in the Australian irrigation sector as the first and only agricultural water-use efficiency system to collect real-time data on crop water stress status and subsequently predict future water requirements. However, CSIRO emphasises that WaterWise is intended to form an integrated approach to water stress management and serve as a complementary, not competing, technology for precision agriculture.

CSIRO invested $5.6 million in WaterWise through the Digiscape FSP to date, involving a team of 15 multidisciplinary researchers spanning agronomy, data science, climatology, computer science, and social sciences. CSIRO funding spans 5 years starting in FY2017–18 and concluding in FY2020–21. This program builds on earlier research co-funded by CSIRO and the Cotton Research and Development Corporation (CRDC) establishing temperature thresholds for cotton. Following on this earlier work, CSIRO Waterwise initiative developed new non-crop specific predictive algorithms, models and prototypes enabling rapid development and adaption of irrigation decision making frameworks that could be applied to multiple high value crops. In the future, WaterWise aims to scale from using single in-field canopy sensors to using spatial measures over large areas via drones or satellites.

WaterWise is currently in commercial development through the commercial partner, Goanna Ag. As such, this case study proposes multiple adoption scenarios that may characterise the range of socioeconomic outcomes from WaterWise's future use. Each scenario postulates impact potential based on the scientific and economics literature related to the use of information and consequent adjustments in behaviour in the agriculture value chain.

1.3 Goanna Ag

Goanna Ag, formed in July 2018, is the first commercial partner bringing the WaterWise technology to Australian irrigators. Goanna Ag is an agtech company and a known manufacturer of low-cost, low-power, and long-range agricultural sensing systems for water use efficiency in Australia. They will be supplying WaterWise's advanced analytics system to their on-farm clients through GoField, a Goanna Ag irrigation management system. With the addition of WaterWise's technology, GoField has many benefits including:

- measuring the water available to a particular crop,
- forecasting water requirements,
- facilitating optimised water scheduling and irrigation practices, and
- assessing efficiency of irrigation after applying water.

Although no other companies are licensing WaterWise today, interested companies can contact CSIRO to discuss potential partnerships.

1.4 Case Study Purpose

Case studies are included as a key component of CSIRO's evaluation and performance measurement program for the purpose of evaluating the outcomes and impacts of CSIRO research and innovation activities. As outlined in CSIRO's impact evaluation framework, case studies must clearly describe the rationale behind CSIRO's investment, action, and participation in the research, as well as the actual or projected outcomes and impacts across social, environmental, and economic dimensions. CSIRO's preferred method for case study evaluation is cost-benefit analysis (CBA).

RTI International, an independent non-profit research institute, was commissioned to conduct the WaterWise analysis. This case study provides a framework for assessing and quantifying the potential social, environmental, and economic impact of adopting the WaterWise technology. The purpose of this analysis is to provide a comprehensive summary of the potential impact of this technology on the agriculture sector.

As mentioned above, Goanna Ag is incorporating WaterWise into its existing GoField system. WaterWise has been continuing to conduct research in collaboration with on-farm growers and industry partners to apply, validate, and test the technology. The next step for its development is to transition from using fixed in-field canopy sensors to spatial sensors such as drones or satellites.

Our report presents a prospective impact analysis using CBA to quantify the net potential benefits of the development, adoption, and implementation of WaterWise in the agriculture sector from 2021 through 2030. To account for uncertainty, the case study included three different adoption scenarios (low, medium, high) for four different commodities (cotton, sugarcane, tomatoes, and almonds). The results of this analysis are intended to inform CSIRO's performance management, accountability, communications, and continual improvement.

2. WaterWise's Potential Economic Net Benefits

The potential benefits for Australia from developing and adopting WaterWise are broad. Our CBA approach used historical market data, existing research on the impact of improved yield projections, and interviews with WaterWise's developers.

We implemented a benefit transfer approach (Brander & Schuyt, 2010). In this approach, researchers leverage insights and results from other studies that are topically, regionally, contextually, or methodologically relevant to the research questions or case studies at hand. Following best practices in economics, we transferred values from the literature to support our modelling work for each case study.

Our analysis is prospective because the technology remains in commercial development. As such, all estimates presented herein should be interpreted as probable, should adoption, impact, and use cases emerge as hypothesised. **Overall, we recommend focusing interpretation on the direction and magnitude of benefits rather than the specific quantitative value.**

We developed projections of potential impacts for 2021 through 2030. We present the net present value (NPV) of benefits using a 7% annual discount rate (2020 base year and in 2020 dollar terms) consistent with CSIRO's impact evaluation guidance (2020).

2.1 Adoption and Impact Scenarios

Given its pre-market status and the limited historical data on usage and impact, this case study offers estimates of potential value based on ranges of estimated uptake and user benefits. We designed future scenarios that cover potential outcomes based on an overall assessment of how WaterWise could generate impacts. Three adoption scenarios (low, medium, and high) and three impact scenarios (small, moderate, and large) combined to present nine total impact scenarios. (Scenarios are described in greater depth in each impact segment.) We also focused on four crops because they represent important commodities to the Australian agriculture industry with historically higher than average water intensive production.

In brief, adoption scenarios represent the potential uptake of WaterWise across each of commodity. These scenarios are based on historical adoption rates for similar products, where available (Table 2.1). Conservative estimates are used where there are limited historical data. The counter factual to these adoption scenarios is the assumption of a status quo in terms of irrigation efficiency and productivity.

Our impact scenarios are designed to capture the uncertainty around the potential direct impacts of WaterWise for producers of each commodity analysed. As with the adoption scenarios, these have been designed using historical data or previous literature, and use conservative estimates where data are limited (Table 2.2). Details on the development of these scenarios are presented below.

Table 2.1. Projected Annual Adoption Rates by Adoption Scenario by Commodity with Percentages Representing the Proportion of Harvested Area Using WaterWise (2021-2030)

Use Case	Adoption Scenario	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Cotton	Low	**1%**	1%	2%	3%	5%	7%	10%	14%	21%	**30%**
	Medium	**1%**	2%	2%	4%	6%	9%	14%	21%	32%	**50%**
	High	**1%**	2%	3%	4%	7%	11%	17%	27%	44%	**70%**
Sugar	Low	**1%**	1%	2%	3%	5%	7%	10%	14%	21%	**30%**
	Medium	**1%**	2%	2%	4%	6%	9%	14%	21%	32%	**50%**
	High	**1%**	2%	3%	4%	7%	11%	17%	27%	44%	**70%**
Tomatoes	Low	**1%**	1%	2%	3%	5%	7%	10%	14%	21%	**30%**
	Medium	**1%**	2%	2%	4%	6%	9%	14%	21%	32%	**50%**
	High	**1%**	2%	3%	4%	7%	11%	17%	27%	44%	**70%**
Almonds	Low	**1%**	1%	2%	3%	5%	7%	10%	14%	21%	**30%**
	Medium	**1%**	2%	2%	4%	6%	9%	14%	21%	32%	**50%**
	High	**1%**	2%	3%	4%	7%	11%	17%	27%	44%	**70%**

For each adoption scenario we assumed initial market share of 1% growing to a maximum market share of 30%, 50%, and 70% by 2030. We apply a compound average annual growth rate to estimate market potential in the years between 2021 and 2030. We capped the market adoption potential at 70% in the high adoption case the share of growers that currently utilize some type of irrigation management system. While it is possible that WaterWise could garner a larger share of the irrigation market, we felt that the conservative estimate provides a reasonable upper bound.

Table 2.2. Projected Annual Impact Rate Scenarios for Water Savings and Yield Changes

Use Case	Impact Scenario	Water Savings[a]	Yield Change[a]
Cotton	Small	5%	0.5%
	Moderate	15%	3.3%
	Large	35%	4.5%
Sugar	Small	5%	0.5%
	Moderate	15%	3.3%
	Large	35%	4.5%
Tomatoes	Small	5%	0.0%
	Moderate	15%	0.1%
	Large	35%	3.0%
Almonds	Small	5%	0.0%
	Moderate	15%	0.1%
	Large	35%	3.0%

[a] Personal communication with Dr. Rose Roche in August, 2021.

The impact scenarios include three levels of improved water efficiency and productivity improvements (CRCD, 2021). We assume the range of water savings are the same across the four use cases.

For yield impacts, the ranges are based on discussion with the CSIRO research team about the known impacts to field crops, specifically cotton and sugarcane. The value for small yield impact was intended to reflect a negligible change in productivity with WaterWise technology. Moderate yield impact of 3.3% represents the average of three sets of results from CSIRO cotton field studies provided in personal communication with CSIRO project team. The high yield impact was the upper bounds of the results from the cotton field study tests. The same yield impacts have not been observed in preliminary field test for tomatoes. For this reason, we apply relatively lower yield impacts for the tomatoes and almond use cases. It is important to note that Waterwise is still a nascent technology expanding to other commodities and may have more measurable impacts on yields. For the purposes of this analysis, we apply zero or near zero yield changes for the small and moderate scenarios, and used a rate similar to the average observed in cotton field studies for the high scenario.

2.2 Additional Key Parameters

In addition to the adoption and impact rates presented in the previous section there are several additional key parameters we use to calculate the economic impacts which are presented in Table 2.3.

Table 2.3. Parameters Used to Calculate Water, Energy and Yield Impacts

Parameter	Units	Cotton	Sugar	Tomatoes	Almonds
Harvested area	ha	325,459	181,593	4,618	30,171
Water demand	ML/ha/yr	7.55	5.60	7.00	10.97
Energy demand	MJ/ha/yr	9,450	10,343	24,000	11,236
Commodity yield	t/ha	2.0	86.1	97.8	3.0
Commodity price	$/t	$2,608	$42	$1,309	$150
Water price	$/ML water	$245	$245	$245	$245
Diesel price	$/l	$1.12	$1.12	$1.12	$1.12
Electricity price	$/kWh	$0.08	$0.08	$0.08	$0.08

The harvested area represents a 5-year historical average of national harvested area between 2015 and 2019 for each commodity. For prospective years in the analysis, we assumed that harvested area was static. Cotton and sugarcane values were based on Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) annual agricultural outlook statistics. Unfortunately, similar statistics were not available from ABARES for tomatoes and almonds. For tomatoes, historical harvested area and yield statistics were obtained from the Food and Agricultural Organization's FAOSTAT database (2020). For almonds, area and yield values were obtained from a market report by the Almond Board of Australia (2021).

Water demand for each crop was identified through various public reports and literature. Water demand values for cotton and almonds were obtained from a water market research report by ABARES (Goesch et al., 2020). Sugarcane water demand was obtained from a market report by Sugar Research Australia (Walsh & Powell, 2017). Tomatoes' water demand was obtained from an irrigation technology review published by the Horticulture Innovation Australia (Yiasoumi, 2016). When sufficient data were available, the authors calculated historical 5-year averages.

The average water price was calculated using historical prices for years 2015 and 2019 from Goesch et al. (2020) for NSW northern MDB regions Gwydir, Lachlan, Macquarie-Castlereagh, and Namoi.

We calculated the average diesel price using the historical farm fuel base prices for off-road diesel (2015–2020) from the ACS 2020. We then applied a 10% goods and services tax (GST) and a fixed excise tax of 0.3814 cents per litre.

Electricity price was assumed to be approximately similar to the average commercial electricity price in developed nations.

The subsequent sections of this report detail the methods we used to calculate the net benefits associated with adopting the WaterWise technology.

2.3 Quantification Approach

2.3.1 Benefits—Improved Water Efficiency

WaterWise provides producers with improved information about crops stress levels, allowing them to make real-time adjustments to irrigation scheduling, ultimately leading to improvements in water use efficiency. The associated water savings lead to operational cost savings water purchases are reduced and energy costs associated with irrigation pumping are reduced. The following subsections briefly describe the calculation methods we used to estimate the operational savings. Readers should note that the analysis assumes a constant area of production over time and does not attempt to model growers' decisions to expand the total area of production in future years. Presumably any expansion in production area would erode the operational cost savings from the water efficiency and energy savings.

To estimate the economic benefits from reduced water consumption, we used the following formula:

$$Total\ Benefits = \ WaterSavings + EnergySavings + YieldRev$$

where:

Water Savings

To estimate water savings, we used the following formula:

$$WaterSavings = \ \left(Adopt\%_{AS,t} * HarvestArea_{commodity}\right) * \left(Eff\%_{IS} * WaterDemand_{commodity}\right) * WaterPrice$$

where:

$Adopt\%$ = percentage of producers adopting WaterWise (%) delineated by scenario and year

$HarvestArea$ = current national harvested area (hectares) by commodity

$Eff\%$ = water efficiency improvement (%) delineated by scenario

$WaterDemand$ = average annual water demand (ML ha^{-1} yr^{-1})

$WaterPrice$ = average water price (\$ ML^{-1})

Energy Savings

To estimate the economic benefits from reduced water consumption, we used the following formula:

$$EnergySavings = \left(Adopt\%_{AS,t} * HarvestArea_{commodity}\right) * \left(Eff\%_{IS} * WaterDemand_{commodity}\right) * EnergyDemand * [(50\% * DieselPrice) + (50\% * ElecPrice)]$$

where:

$Adopt\%$ = percentage of producers adopting WaterWise (%) delineated by scenario and year

$HarvestArea$ = current national harvested area (hectares) by commodity

$Eff\%$ = water efficiency improvement (%) delineated by scenario

$WaterDemand$ = average annual water demand (ML ha^{-1} yr^{-1})

$DieselPrice$ = average off-road diesel price (\$ ML^{-1})

$ElecPrice$ = average commercial electricity price (\$ kWh^{-1})

Yield Improvements

Improved water utilisation and reduction in intervals of crop stress also improve yields. There is reasonable evidence from the historical field study conducted by CSIRO on how yields change for cotton production; however, a similar degree of field observations was not available for the other commodities evaluated in this analysis. We applied the same yield impacts to sugarcane. We assumed zero or limited yield impacts for tomatoes and almonds because we lacked supporting evidence from field studies.

To estimate the increased revenue from yield improvements, we used the following formula:

$$YieldRev = \left(Adopt\%_{AS,t} * HarvestArea_{commodity}\right) * \left(YieldChange\%_{IS} * AvgYield_{commodity}\right) * AvgPrice_{commodity}$$

where:

$Adopt\%$ = percentage of producers adopting WaterWise (%) delineated by scenario and year

$HarvestArea$ = current national harvested area (hectares) by commodity

$YieldChange\%$ = water efficiency improvement (%) delineated by scenario

$AvgYield$ = average annual water demand (t ha^{-1} yr^{-1})

$AvgPrice$ = average price of each commodity (\$ t^{-1})

2.3.2 Adoption Costs—Technology Investment

As mentioned earlier in this report, WaterWise technology is available commercially through Goanna Ag. WaterWise technology has been integrated into Goanna's GoField Plus irrigation management system. For the purposes of this analysis, we assumed the implementation cost was $25/ha annually. This cost reflects the annual subscription price of $1,225 for the GoField Plus package and includes the following:

- soil moisture probe (1 probe per ha)
- canopy temperature sensor (1 sensor per ha)
- GoSat platform access, which combines local weather data and forecasts with satellite imagery and analytics using CSIRO-created algorithms to forecast crop water use on a day-by-day basis
- LoRaWAN or CATM1 network access for data connectivity
- the GoApp software for desktop and mobile

While the adoption would presumably require installation of the network of field probes and sensors, our analysis did not explicitly account for these costs.

To estimate the adoption costs to producers, we used the following formula:

$$AdoptionCost_{commodity} = Adopt\%_{AS,t} * HarvestArea_{commodity} * AnnualCost$$

where:

$Adopt\%$ = percentage of producers adopting WaterWise (%) delineated by scenario and year

$HarvestArea$ = current national harvested area (hectares) delineated by scenario

$AnnualCosts$= \$25 ha^{-1}

2.3.3 Net Benefits

Finally, to estimate the net benefits to producers, we used the following formula:

$$Net\ Benefits = (WaterSavings + EnergySavings + YieldRev) - AdoptionCost$$

Net benefits are simply the sum of the annual benefits minus the technology implementation costs.

2.4 Results

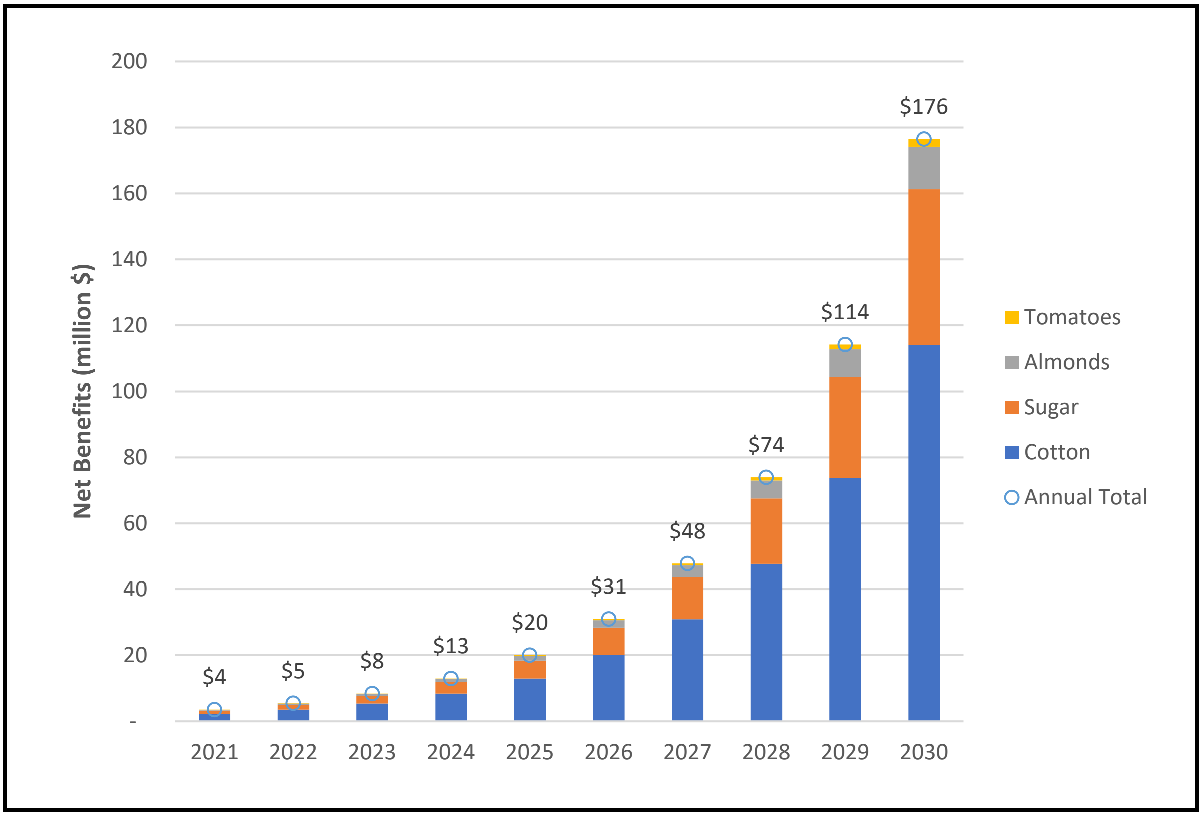
The analysis results presented in this section represent the medium adoption and moderate impact scenarios. For full set of results, see Appendix A.

Figure 2.1 shows the annual net benefits over the 10-year period for the medium-moderate scenario before discounting to 2020. Over 93% of the net benefits come from cotton and sugarcane production, with the remaining 7% attributed to tomatoes and almond production.

Average harvested area is the key factor driving the difference in results between the four commodities (see Table 2.3). While cotton and sugarcane have similar production footprints, the harvested areas for tomatoes and almonds are significantly smaller. The land area associated with cotton production is more than 10 times larger than almonds and over 70 times larger than the tomatoes area.

While the production segments for tomatoes and almonds are smaller, they represent higher value products, where improved yields and quality resulting from optimal irrigation may strengthen domestic producers' ability to capture a greater share of international export markets.

Figure 2.1. Annual Net Benefits (million $) by Commodity for Medium-Moderate Scenario



Notes: Net benefits shown here are before discounting to 2020.

Table 2.4 presents the aggregated annual increase in harvested acres using the WaterWise technology system under the medium–moderate scenario and the corresponding savings for water and energy and yield improvements.

Table 2.4. Water, Energy, and Yield Impacts by Year for Medium–Moderate Scenario

Year	Harvested Area with WaterWise (ha)	Water Savings (ML)	Electricity Savings (MWh)	Fuel Savings (litres)	Yield Expansion (tonnes)
2021	5,418	5,755	7,964	746,636	5,312
2022	8,368	8,889	12,300	1,153,144	8,204
2023	12,925	13,728	18,997	1,780,976	12,670
2024	19,962	21,203	29,340	2,750,632	19,568
2025	30,830	32,747	45,314	4,248,219	30,222
2026	47,615	50,576	69,986	6,561,171	46,676
2027	73,539	78,112	108,090	10,133,414	72,090
2028	113,578	120,640	166,939	15,650,573	111,339
2029	175,415	186,323	257,830	24,171,561	171,958
2030	270,920	287,767	398,206	37,331,818	265,580
Grand Total	**758,570**	**805,741**	**1,114,967**	**104,528,145**	**743,618**

Cumulatively over 10 years, WaterWise technology adoption would result in over 806 gigalitres of water savings. As a point of reference, this amount of water savings is approximately 62% of the total irrigation water used for cotton production nationally in FY2019–20 (Australian Bureau of Statistics, 2021). Significant energy savings were also achieved through avoided fuel consumption associated with running irrigation pumping systems.

Monetizing these savings provides perhaps a more nuanced view of WaterWise's potential impacts. Table 2.5 presents the cumulative economic benefits associated with each impact metric under the same middle-of-the-road scenario.

Table 2.5. Water, Energy, and Yield Benefits (million $) by Commodity for Medium–Moderate Scenario

Use Case	Benefits of Water Savings	Benefits of Energy Savings	Benefits of Yield Changes	Real Costs	Net Benefits
Cotton	126.18	124.24	79.16	11.39	319.18
Sugar	52.23	56.74	29.74	6.36	132.35
Almonds	17.00	20.06	0.02	1.06	36.01
Tomatoes	1.66	4.19	0.83	0.16	6.51
Total	**197.06**	**206.21**	**109.75**	**18.96**	**494.06**

Note: Values represent the cumulative benefits/costs accrued over the 10-year time horizon before discounting to 2020.

In total, the benefits associated with water and energy savings represent 80% of the total benefits, while revenue gains from increased yields account for the balance. Adoption costs are less than 4% of the total benefits.

Looking across the commodities, we see that the energy savings are larger than the water savings for almonds and tomatoes. This information may be useful when developing engagement strategies for specific producer segments.

3. Discussion

3.1 Summary Quantitative Impact Analysis Results

Table 3.1 presents the total NPV of impacts (in millions of 2020 dollars) across each impact and adoption scenario. (Table A.1 and Table A.2 in Appendix A present the average annual benefits across each use area and total NPV of benefits across each use area, respectively.)

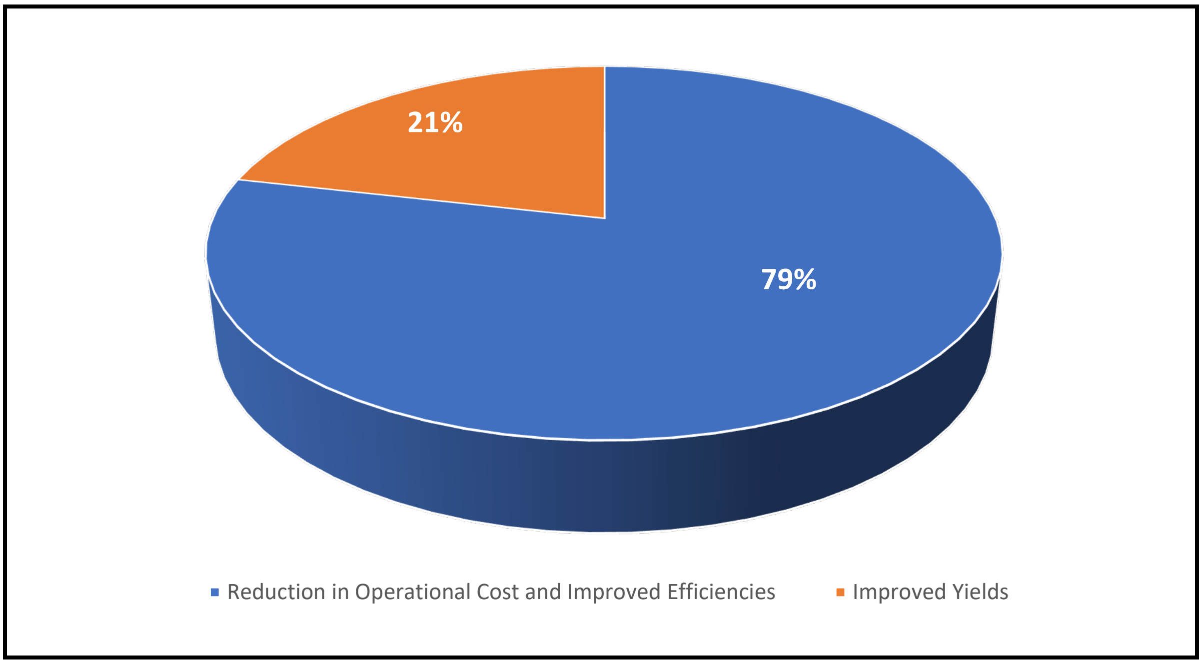
Table 3.1. NPV of Total Benefits (million $, 2020)

Adoption Scenario	Impact Scenario		
	Small	Moderate	Large
Low	47.7	179.6	399.7
Medium	64.5	265.2	590.2
High	91.8	345.7	769.4

Notes: NPV was calculated using a 7% real social discount rate for the period from 2021 through 2030.

The marginal impact from moving from lower to higher **impact** scenarios is much greater than moving from lower to higher **adoption** scenarios. Additionally, the largest source of benefits comes from reductions in operational costs and improved efficiency in water usage (79% of the total benefits in the medium–moderate impact scenarios), followed by improvements in production yields (21% of the total) (Figure 3.1).

Figure 3.1. Distribution of Benefits in the Medium Adoption–Moderate Impact Scenario



If adoption is medium but the overall impact is small, one would anticipate approximately $64.5 million in social value creation over the period 2021 through 2030. However, if impacts are greater, the same level of adoption could generate social value of $590 million. Note that additional results are presented in Appendix A, including average annual discounted benefits for each sector and scenario (Table A.1); the NPV of total benefits to each sector across scenarios (Table A.2); and the range of average annual discounted benefits by sector (Figure A.1).

3.2 Summary Qualitative Impact Analysis Results

Additional social benefits have not been monetised in this study, but they are nonetheless significant.

The estimated energy savings of this technology represents a significant reduction in greenhouse gas emissions. We estimated that WaterWise under the various adoption and impact scenarios could realise CO_2 emissions reductions ranging between 111 and 1,544 kilotonnes. These reductions are equivalent to removing approximately 336,000 passenger vehicles from the road for 1 year or avoiding 186,000 households' annual energy consumption. See the full set of CO_2 emissions reduction estimates in Table A-5.

As mentioned earlier, WaterWise offers significant water savings, and sustained adoption of the technology system over a period of multiple years will generate measurable improvements in water resource availability and reduce agriculture's reliance on groundwater and surface water for irrigation in times of extended drought.

Additionally, increased yield on field crops such as cotton and sugarcane increases food security within Australia. Also, as a net exporter, growth in yields would likely lead to a small increase in commodity exports for producers.

Finally, improvements in information on yield can allow insurers and financial institutions to better value farms and project seasonal yields, which will allow them to better estimate risk. These outcomes, in turn, could potentially reduce the cost of insurance or capital and expand access to these resources to a wider audience (CSIRO, n.d.).

3.3 Concluding Remarks

In addition to present value estimates, we also calculated internal rate of return (IRR) and benefit-costs ratios (BCR) for each scenario. Between 2015 and 2018, $5.48 million was invested in WaterWise over 5 years. Our estimates resulted in an IRR ranging from 42% to 106% across all scenarios. Additionally, we found that the BCR ranges between 10.0 and 162.3 across the lowest and highest scenarios (see Table 3.2 for a full range of results).

Reductions in operational costs (either through direct water savings and energy savings) are significant and thus constitute the largest proportion of benefits. There are also potential revenue gains due to yield improvements.

Additionally, the results of our analysis reveal an unanticipated finding. Water savings may not be the dominant benefit for all crop producers. For tomato and almond producers, fuel savings outweighed the water savings benefits. This finding suggests that in future efforts to accelerate adoption in new target commodities, tailoring WaterWise's value proposition to emphasise different key benefits may make engagement strategies more effective.

Table 3.2. Economic Performance Measures for Each Adoption–Impact Scenario

Scenario	BCR	IRR
Low–small	7.7	38%
Medium–small	10.5	41%
High–small	14.9	46%
Low–moderate	29.2	65%
Medium–moderate	43.1	71%
High–moderate	56.2	74%
Low–large	64.9	89%
Medium–large	95.9	94%
High–large	125.0	97%

References

ABARES. (2020). *Agricultural commodity statistics 2020*. https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/data#2020

Almond Board of Australia. (2021). *Almond insights 2020-2021*. https://australianalmonds.com.au/wp-content/uploads/2021/08/2021_Almond_Insights_soft_copy.pdf?v=6cc98ba2045f

Australian Bureau of Statics (ABS). (2021). *Water use on Australian farms FY2019-20*. https://www.abs.gov.au/statistics/industry/agriculture/water-use-australian-farms/latest-release.

Australian Bureau of Statics (ABS). (2015). *Water use on Australian farms FY2013-14*.

Brander, L., & Schuyt, K. (2010). *Benefits transfer: The economic value of world's wetlands*. TEEBweb.org

Cotton Research and Development Corporation (CRDC). (2021). Smarter Irrigation for Profit Phase II Cast Studies, "Responsive irrigation Management with Canopy Temperature Stress technology". https://smarterirrigation.com.au/wp-content/uploads/2021/01/Canopy-Temperature-Stress-CTS-technology-in-cotton-production-Jan-2021.pdf.

Commonwealth Scientific and Industrial Research (CSIRO). (2020). *Impact evaluation guide*. https://www.csiro.au/en/About/Our-impact/Evaluating-our-impact

Commonwealth Scientific and Industrial Research (CSIRO). (n.d). *Future proofing agricultural production though superior understanding of crop stress responses and responsive management practices*. Internal white paper on WaterWise opportunities.

Food and Agriculture Organization. (2020). FAOSTAT database. http://www.fao.org/faostat/en/#home

Goesch, T., Legg, P., & Donoghoe, M. (2020). *Murray-Darling Basin water markets: Trends and drivers 2002-03 to 2018-19*. Figure 32 Irrigation water use per hectare, selected irrigated horticulture industries, MDB, 2005-06 to 2017-18. Research report 20.5. Published by the Australian Bureau of Agricultural and Resource Economics and Sciences. https://www.agriculture.gov.au/abares/research-topics/water/murray-darling-basin-trends-and-drivers

Personal communication with Dr. Rose Roche, CSIRO Agriculture and Food. August 18th, 2021.

U.S. Department of Agriculture (USDA). (2021). *Report: Cotton products annual, Canberra, Australia*. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Cotton%20and%20Products%20Annual_Canberra_Australia_04-01-2021

Welsh, J., & Powell, J. (2017). *Opportunities for energy innovation in Australian irrigated sugarcane*. Sugar Research Australia report. Ag Econ, Burren Junction, NSW, Australia. https://sugarresearch.com.au/sugar_files//2018/01/Energy-in-irrigated-cane_2017x.pdf

Yiasoumi, B. (2016). *Final report: Review of current irrigation technologies*. Report No. VG14048. Horticulture Innovation Australia. https://ausveg.com.au/app/uploads/technical-insights/VG14048.pdf

Appendix A: Supplemental Results

Table A.1. Average Annual Benefits Across Industry and Scenarios from 2021–2030 (million $)

Use Case	Average Annual Benefits 2021–2030 (million $)								
	Small			Moderate			Large		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Cotton	3.1	4.5	5.9	11.6	17.1	22.3	24.9	36.8	48.0
Sugar	1.2	1.2	2.4	4.8	7.1	9.3	10.5	15.5	20.2
Tomatoes	0.1	0.1	0.1	0.2	0.3	0.5	1.4	2.1	2.7
Almonds	0.4	0.6	0.8	1.3	1.9	2.5	3.1	4.6	6.0
Total	**4.8**	**6.5**	**9.2**	**18.0**	**26.5**	**34.6**	**40.0**	**59.0**	**76.9**

Notes: NPV was calculated using a 7% real social discount rate for the period from 2021 through 2030.

Table A.2. NPV of Total Benefits Across Industry and Scenarios from 2021–2030 (million $)

Use Case	Total Discounted Benefits 2021–2030 (million $)								
	Small			Moderate			Large		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Cotton	30.5	45.1	58.8	116.1	171.4	223.4	249.3	368.1	479.8
Sugar	12.4	12.4	23.9	48.1	71.0	92.6	105.2	155.3	202.5
Tomatoes	0.6	1.0	1.2	2.4	3.5	4.6	14.0	20.6	26.9
Almonds	4.1	6.0	7.9	13.1	19.3	25.2	31.3	46.2	60.3
Total	**47.7**	**64.5**	**91.8**	**179.6**	**265.2**	**345.7**	**399.7**	**590.2**	**769.4**

Notes: NPV was calculated using a 7% real social discount rate for the period from 2021 through 2030.

Figure A.1. Range of Average Annual Benefits by Sector for Each Adoption and Impact Scenario Pair

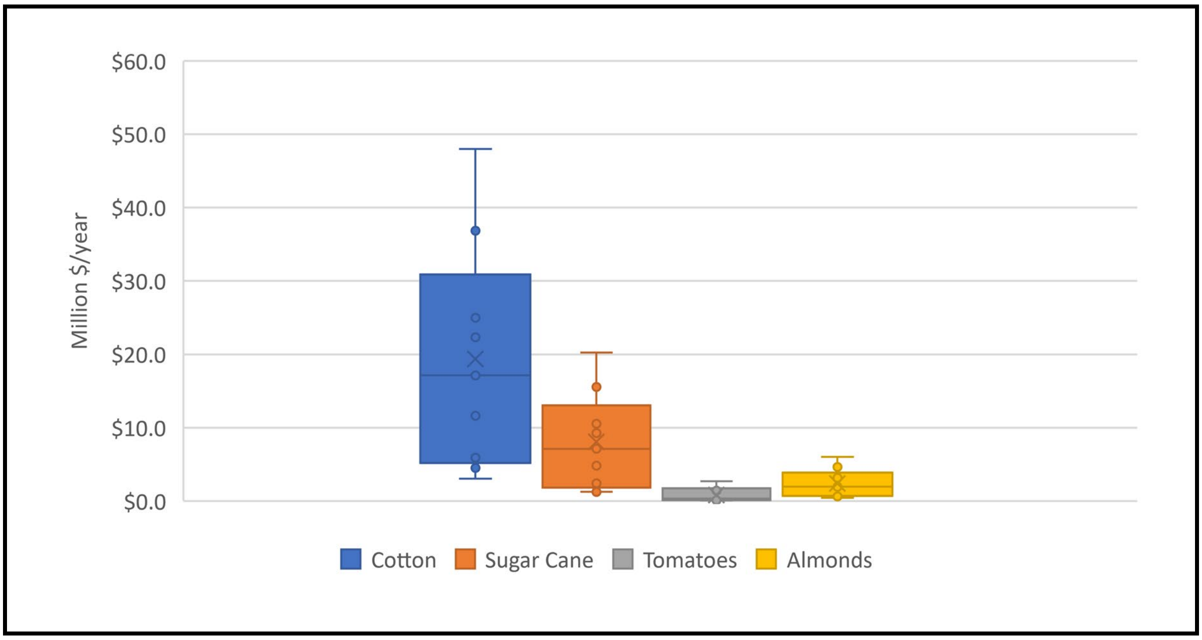


Table A.3. NPV of Operational Savings Benefits Across Commodities and Scenarios from 2021–2030 (million $)

Use Case	Small			Moderate			Large		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Cotton	30.5	45.1	58.8	91.6	135.3	176.4	213.8	315.8	411.6
Sugar	13.2	13.2	25.5	39.7	58.7	76.5	92.7	136.9	178.4
Tomatoes	0.7	1.0	1.4	2.1	3.1	4.1	5.0	7.3	9.6
Almonds	4.5	6.6	8.7	13.5	19.9	26.0	31.5	46.5	60.7
Total	**49.0**	**66.0**	**94.3**	**147.0**	**217.1**	**283.0**	**343.0**	**506.5**	**660.2**

Notes: NPV calculated using a 7% real social discount rate for the period from 2021 through 2030.

Table A.4. NPV of Revenue due to Yield Changes Across Commodities and Scenarios from 2021–2030 (million $)

Use Case	Small			Moderate			Large		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Cotton	4.4	6.5	8.5	28.9	42.6	55.5	39.9	58.9	76.7
Sugar	1.7	1.7	3.2	10.8	16.0	20.9	15.0	22.1	28.8
Tomatoes	-	-	-	0.3	0.4	0.6	9.1	13.4	17.4
Almonds	-	-	-	0.0	0.0	0.0	0.2	0.3	0.4
Total	**6.1**	**8.2**	**11.7**	**40.0**	**59.1**	**77.0**	**64.1**	**94.7**	**123.4**

Notes: NPV was calculated using a 7% real social discount rate for the period from 2021 through 2030.

Table A.5. CO_2 Emission Reductions from Energy Savings Across Commodities and Scenarios from 2021–2030 (kt CO_2)

Use Case	Small			Moderate			Large		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Cotton	68	102	134	203	305	402	474	712	938
Sugar	31	31	61	92	138	182	215	323	425
Tomatoes	2	3	4	7	10	13	16	24	31
Almonds	11	16	21	33	49	64	76	114	150
Total	**111**	**152**	**221**	**334**	**503**	**662**	**780**	**1,173**	**1,544**

Notes: Emissions factors include 2.68 kg CO_2/litre and 0.20 kg CO_2/kWh for diesel and electricity, respectively.

Table A.6. Monetised Benefits of CO_2 Emission Reductions Across Commodities and Scenarios from 2021–2030 (million $)

Use Case	Small			Moderate			Large		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Cotton	0.95	1.42	1.88	2.84	4.27	5.63	6.63	9.97	13.13
Sugar	0.43	0.43	0.85	1.29	1.94	2.55	3.01	4.52	5.95
Tomatoes	0.03	0.05	0.06	0.09	0.14	0.19	0.22	0.33	0.44
Almonds	0.15	0.23	0.30	0.46	0.68	0.90	1.06	1.60	2.10
Total	**1.56**	**2.13**	**3.09**	**4.68**	**7.04**	**9.27**	**10.92**	**16.42**	**21.62**

Notes: Assumed national average carbon price of $14 per tonne of CO_2.

RTI International is an independent, nonprofit research institute dedicated to improving the human condition. Clients rely on us to answer questions that demand an objective and multidisciplinary approach—one that integrates expertise across the social and laboratory sciences, engineering, and international development. We believe in the promise of science, and we are inspired every day to deliver on that promise for the good of people, communities, and businesses around the world.

For more information, visit www.rti.org.