Contemporary trends and drivers of irrigation in the southern Murray-Darling Basin

by Aither
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February 2016

RIRDC Publication No 16/007
RIRDC Project No 010331
Foreword

The southern Murray-Darling Basin (sMDB) is Australia’s largest and highest value irrigation area, with around $5 billion per year in irrigated agricultural production. The continued success of this nationally significant irrigation area depends on an enormous number of private and public decisions, responding to and informed by current and future trends in water markets and irrigated agriculture.

Although some decision makers in the sMDB have a good understanding of current and future trends in irrigated agriculture as they relate to their industry and region, they typically have less knowledge outside their direct area of involvement. Likewise, public policy experts who are responsible for making decisions at basin or national scales may have a good understanding of policy principles but difficulty following contemporary trends that are most evident at industry and regional levels.

There is substantial uncertainty regarding current and future trends in water markets. On the supply side, there has been a marked shift towards lower inflows to storages in the sMDB over an extended period. At the start of 2016, some parts of the sMDB, particularly in Victoria, have experienced serious and severe rainfall deficiencies over the past 19 months, and there is uncertainty over what might happen in the future, especially in light of climate change. There has also been a large reallocation of water to the environment through a combination of buybacks and infrastructure programs, with the prospect of further reallocation. On the demand side, there has been a rapid expansion in the cotton industry in the sMDB and a boom in investment in the nuts industry. There is the prospect of significant increases in water demand by these and other high value industries over the next five years, which combined with reduced water supply, could have important implications for water markets and irrigated agriculture.

The importance of this report is that it brings together qualitative and quantitative evidence held by stakeholders across the sMDB to identify key current and future trends for individual industries and regions; explores the aggregate implications of these trends for water markets; and examines the overall consequences for individual industries and regions.

This project was funded from RIRDC Core Funds which are provided by the Australian Government.

This report is an addition to RIRDC’s diverse range of over 2000 research publications and it forms part of our National Rural Issues R&D program, which aims to inform and improve the policy debate by Government and industry on national rural issues in Australia.

Most of RIRDC’s publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

Craig Burns
Managing Director
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About the Author

Aither is an Australian economics and public policy advisory firm with deep expertise in water management, infrastructure and utility industries, the environment and natural resources. Aither is a leading provider of independent water market advisory services in the Murray Darling Basin and beyond. We provide economic, policy, and strategic commercial advice, analysis and insights to policy makers, regulators and market participants. Through our work, we aim to support and inform better policy and decision making.

Our team is made up of water market experts. We have led and advised on the development, implementation and assessment of major entitlement and market reforms across Australia. Our recent work has developed new models for understanding water supply and demand, informed large commercial transactions in water entitlements, and supported market participants in the development and implementation of innovative trading strategies. Our team is frequently sought after to present internationally on Australia’s water entitlement and market reforms.

In December 2015, Aither received the Australian Water Association Research Innovation Award (Victoria) for the development of our freely available annual Aither Water Markets Report. These reports, along with all our independent periodic market reporting to our clients, are underpinned by our comprehensive database of trading activity and responsive approach.

With established relationships with policy makers, system operators and market participants, we have a deep understanding of contemporary trends and drivers and offer unparalleled insights. Aither understands the real risks and opportunities associated with water markets, and provide an independent perspective to decision makers.

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Abbreviations

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<tr>
<th>GL</th>
<th>Gigalitre (one billion litres)</th>
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<tr>
<td>GVIAP</td>
<td>Gross Value of Irrigated Agricultural Production</td>
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<tr>
<td>ML</td>
<td>Megalitre (one million litres)</td>
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<tr>
<td>NRM</td>
<td>Natural Resource Management</td>
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<tr>
<td>RIRDC</td>
<td>Rural Industries Research and Development Corporation</td>
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<tr>
<td>sMDB</td>
<td>Southern Murray-Darling Basin</td>
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Executive Summary

What the report is about?

This study draws on evidence from multiple sources to report on recent and future trends in irrigated agriculture in the southern Murray-Darling Basin (sMDB).

Who is the report targeted at?

The report is targeted at public and private decision makers who stand to benefit from improved understanding of current and future trends in irrigated agriculture and water markets in the sMDB.

Background

Although some decision makers have a good understanding of current and future trends in irrigated agriculture as they relate to their industry and region, they typically have less knowledge about other industries and regions. This matters because irrigated agriculture in the sMDB is linked through markets, including water markets, so changes to one industry invariably affects other industries. Likewise, public policy experts who are responsible for making decisions at national and basin scales may have a good understanding of policy principles but difficulty following contemporary trends that are most evident at industry and regional levels. Understanding contemporary trends is important in making better decisions, ensuring that the implementation of programs and policies is effective, and to avoid sending mixed signals.

There is substantial uncertainty regarding current and future trends in water markets. On the supply side, there has been a marked shift towards lower inflows to storages in the sMDB over an extended period. At the start of 2016, some parts of the sMDB, particularly in Victoria, have experienced serious and severe rainfall deficiencies over the past 19 months (BOM 2016), and there is uncertainty over what might happen in the future, including in light of climate change. There has also been a large reallocation of water to the environment through a combination of buybacks and infrastructure programs, with the prospect of further reallocation. On the demand side, there has been a rapid expansion in the cotton industry in the sMDB and a boom in investment in the almond industry. There is the prospect of significant increases in water demand by these and other high value industries over the next five years, which combined with reduced water supply, could have important implications for water markets and irrigated agriculture.

Aims/objectives

The objectives of this rapid assessment are:

- to bring together qualitative and quantitative evidence held by stakeholders across the sMDB to identify key current and future trends for individual industries and regions
- to explore the aggregate implications of these trends – in particular, what does it mean for water prices?
- to briefly analyse the overall consequences for individual industries and regions, considering the feedback effects of any changes in water prices.

Methods used

Aither used a combination of literature review and consultation with stakeholders throughout the sMDB to assemble multiple sources of evidence around trends and drivers. Aither visited the Riverland, Sunraysia, Goulburn and Riverina regions to discuss trends and drivers with irrigators, water authorities, government departments, water brokers, agricultural consultants, processing
companies and industry groups. Visits were also conducted in Adelaide, Canberra and Melbourne. The resulting information was analysed both qualitatively and, where possible, quantitatively using statistical techniques and economic modelling.

**Results and key findings**

Across the sMDB there has been a downward trend in the number of agricultural businesses irrigating of around 4 per cent per year between 2005-06 and 2013-14, adjusting for seasonal conditions. The regions with the largest declines in percentage terms are North East Victoria, Mallee and SA MDB. These trends are consistent with the amalgamation of irrigation businesses, with fewer businesses operating a similar area of irrigated land. Controlling for the impact of seasonal conditions, there were substantial positive trends in water use for cotton and fruits and nuts in the ABS data. There were large negative trends for dairy and grapes. Water application rates per hectare were largely stable. The exception was 2010-11 when there was a noticeable reduction in water application rates across all of the industries considered due to high water prices.

Notwithstanding the high profitability of some industries, such as cotton and nuts, the overall profitability of irrigated agriculture in the sMDB was frequently poor over the last decade according to ABARES data. Average farm cash income was around $75 000 per year, while average farm business profit was negative at around $-10 000 per year. To some extent this was due to high water prices caused by droughts and, to a lesser extent, environmental water purchases.

Many irrigators have survived the extended period of low profitability through borrowing, with some now carrying substantial debt relative to their assets. Others, especially those with smaller land holdings, have survived through off-farm work, although stakeholders indicated that this has become more difficult as the labour market has deteriorated. The millennium drought drove considerable innovation in the sMDB, including in the dairy industry. Some enterprises did not survive the millennium drought, but many that did developed business plans based around lower water use intensity. For example, dairy farmers increasingly adopted irrigation technologies, such as centre pivot irrigators, that can result in water and labour savings. Some of this investment was subsidised by government programs. Dairy farmers also reduced their use of irrigation water by growing and storing winter crops for summer, rather than irrigating during summer.

There is some evidence that demand for water has firmed over time. According to stakeholders, many irrigators who survived the millennium drought have made substantial on farm investments and are willing to pay more for water than in the past.

Factors other than water are also relevant, with evidence suggesting that changes in commodity prices have been the major driver of recent profitability in many industries, including dairy and wine grapes. In the rice industry, the $93 per tonne increase in producer prices received by rice growers between 2013 and 2014 can be equated, in terms of profitability, to an $80 per ML decrease in the water allocation price.

There has been a rapid expansion in cotton in response to higher profitability compared to alternative activities such as rice. The response to changes in profitability, both positive and negative, has been more gradual for activities with higher capital intensity. The decline in wine grapes has been slow despite persistently low returns for many varieties. This reflects a judgement by most growers that, in the short term at least, the returns from their established wine grape plantings will exceed the returns from redirecting their resources – land, water and labour – to other feasible activities. In the long term, the costs of any major reinvestments, such as upgrading irrigation systems or establishing new wine grape varieties, will also be considered and land use change is more likely to occur.

It has also taken some time for nut plantings to increase in response to high returns. Most new almond developments are on greenfield sites. This gives owners more flexibility to develop their irrigation systems around almonds and exploit the economies of size in almond production. However, even after the decision to establish new almond trees has been made and necessary finance organised, there can
be lengthy delays associated with obtaining regulatory approvals, building water infrastructure and planting the almond trees.

Over the next five years, there is likely to be a substantial expansion in cotton and a small contraction in grapes. Notwithstanding the recent decline in almond prices, there could be a significant expansion in nuts (almonds, walnuts, hazelnuts, pistachios, and so on). An expansion in nuts could substantially reduce the gap between total water availability and total water use by permanent plantings in a repeat of the millennium drought, after accounting for urban and environmental water. This could precipitate extremely high water prices if there is another severe drought, placing pressure on lower value permanent plantings.

A mathematical model was developed to estimate the implications of the future trends in irrigated agriculture and associated changes in water demand, as projected by stakeholders in November and December 2015. Keeping the quantity of entitlements held by environmental water holders constant, water allocation prices are estimated to increase by around 10 per cent in low allocation years and 7 per cent in moderate and high allocation years between 2015-16 and 2020-21. The bulk of the price increase in low allocation years is due to the expansion of nuts, whereas the expansion of cotton has a larger effect in other years. These are short run estimated price effects. There is greater capacity to adjust to higher water prices in the long run through investment and disinvestment, and these adjustments will tend to moderate the price effects of the projected shifts in water demand.

The estimated increases in water prices, along with projected shifts in water demand, are consistent with substantial changes in water use by 2020-21. Water use is estimated to decrease by between 8 to 16 per cent for dairy, rice and grapes. At the same time, water use is estimated to increase by around 65 per cent for cotton and around 18 per cent for fruits and nuts (overall – fruits are likely to decline while nuts increase).

Recent discussions with stakeholders have revealed that some of the projected expansion in nuts is in doubt as a result of the recent fall in almond prices. The potential implications of a smaller than projected expansion in nuts are explored through sensitivity analysis.

**Implications for relevant stakeholders**

The future trends identified in this report present opportunities and challenges. Water markets can have a substantial impact on irrigated agriculture by allowing for the reallocation of water in response to profitability – from lower value to higher value uses. Realising these gains requires open and efficient water markets, including the removal of regulatory trade barriers that do not have a strong rationale. It also requires effective management in the storage and delivery of water.

Stakeholders raised concerns about the adjustment implications of changes in demand (and supply). For example, the trade of water allocations and entitlements from some public irrigation districts in the sMDB has resulted in fixed costs being spread over fewer customers, presenting difficulties for both water authorities and remaining irrigators. The potential for stranded assets is well understood. However, this effect could be worsened by the projected movement of water towards cotton and nuts, especially given that many potential developments are outside public irrigation districts, on greenfield sites. Quantifying the implications of projected changes in water demand for stranded assets is a potential area for further research.

There are also implications for water recovery in the sMDB through infrastructure upgrades to meet the sustainable diversion limits. In particular, there appears to be a risk that a proportion of the infrastructure upgraded could be subsequently underutilised or abandoned as water is traded away. Governments should remain cognisant of possible future trends in water use when providing funding for upgrading water infrastructure. In other words, the challenge is to plan for irrigated agriculture as it will be in 20 years, rather than irrigated agriculture as it is today.
The movement of water into a region can also cause problems. For example, some stakeholders raised concerns about the potential for almond developments below the Choke to increase the risk of delivery congestion.

There are broader structural adjustment issues, some of which are independent of the movement of water. Changes in water use will influence production. The impact on production will depend on the industry. Changes in production would also affect people involved in related industries (such as suppliers and processors) and regional communities. Structural adjustment issues should generally be resolved directly (for example, through regional development and welfare policies) rather than through water policies. As a result, the negative impacts of structural adjustment can be moderated while still enabling water to move to its highest value uses.
1. Introduction

1.1 Objectives

The southern Murray-Darling Basin (sMDB) is Australia’s largest and highest value irrigation area, with around $5 billion per year in irrigated agricultural production. The continued success of this nationally significant irrigation area depends on an enormous number of private and public decisions, including:

- Whether to invest in establishing new permanent plantings?
- Whether to extend a processing plant?
- Whether to maintain a water delivery channel?
- How to prioritise scarce research and development resources?
- Which policies to introduce to alleviate the negative effects of structural adjustment?

In these cases, the optimal decision depends on current and future trends in water markets and irrigated agriculture. For example, whether it is profitable to invest in establishing new permanent plantings is heavily influenced by future water prices, as well as many other factors such as commodity prices and interest rates.

Although some decision makers in the sMDB have a good understanding of current and future trends in irrigated agriculture as they relate to their industry and region, they typically have less knowledge about other industries and regions. This matters because irrigated agriculture is linked through markets, including water markets, so changes to one industry invariably affects other industries. For example, an increase in almond prices leads to an increase in plantings in South Australia, and an increase in demand for water. This increases the price of water, affecting rice production in New South Wales.

Likewise, public policy experts who are responsible for making decisions at basin or national scales may have a good understanding of policy principles but difficulty following contemporary trends that are most evident at industry and regional levels. Understanding contemporary trends is important in making better decisions, ensuring that the implementation of programs and policies is effective, and to avoid sending mixed signals.

There is substantial uncertainty regarding current and future trends in water markets. On the supply side, there has been a marked shift towards lower inflows to storages in the sMDB over an extended period. At the start of 2016, some parts of the sMDB, particularly in Victoria, have experienced serious and severe rainfall deficiencies over the past 19 months (BOM 2016), and there is uncertainty over what might happen in the future, especially in light of climate change. There has also been a large reallocation of water to the environment through a combination of buybacks and infrastructure programs, with the prospect of further reallocation. On the demand side, there has been a rapid expansion in the cotton industry in the sMDB and a boom in investment in the almond industry. There is the prospect of significant increases in water demand by these industries over the next five years, which combined with reduced water supply, could have important implications for water markets and irrigated agriculture.
The objectives of this rapid assessment are:

- to bring together qualitative and quantitative evidence held by stakeholders across the sMDB to identify key current and future trends for individual industries and regions
- to explore the aggregate implications of these trends – in particular, what does it mean for water prices?
- to briefly analyse the overall consequences for individual industries and regions, considering the feedback effects of any changes in water prices.

1.2 Scope

This report focuses on demand side drivers in the water market, while another report prepared by Aither, and funded by the Commonwealth Department of the Environment, focuses on the effects of Commonwealth water buybacks (see Aither 2016). The modelling undertaken for the current report builds previous Commonwealth water buybacks into the baseline, so the effects of demand side drivers are estimated accounting for interactions with previous buybacks.

Irrigated agriculture in the sMDB is extremely complex. There are around 11,000 agricultural businesses irrigating in the sMDB, growing a wide variety of crops, with different soils and climates, irrigation systems, and management practices. The limited budget and time available for this assessment means that the scope is limited to examining the central issues affecting key industries in the sMDB, with a view to developing a contemporary snapshot. While overall trends across all industries are considered, the following industries are examined in additional detail:

- wine grapes
- almonds
- rice
- cotton
- dairy.

The main timespan considered is 2005-06 to 2020-21. This includes 10 years of recent trends in irrigated agriculture, capturing a range of water availability conditions in the sMDB. It also includes 5 years of future trends. While it was possible to develop reasonable projections for 2020-21, there is substantial uncertainty regarding longer term future trends. As a result, trends beyond 2020-21 are considered outside the scope of this assessment.

In this assessment, the sMDB is defined as the following NRM regions:

- Murrumbidgee (or Riverina) and Murray regions in New South Wales
- Mallee, Wimmera, North Central, Goulburn Broken and North East regions in Victoria
- SA MDB in South Australia (Figure 1).
1.3 Summary of approach

Aither used a combination of literature reviews and consultations with stakeholders throughout the sMDB to assemble multiple sources of evidence around trends and drivers. Aither visited the Riverland, Sunraysia, Goulburn and Riverina regions to discuss trends and drivers with irrigators, water authorities, government departments, water brokers, agricultural consultants, processing companies and industry groups. Visits were also conducted in Adelaide, Canberra and Melbourne. The resulting information was analysed both qualitatively and, where possible, quantitatively.

Aither’s approach was developed to account for the complexities of water markets by recognising that irrigators have different preferences around risk, the future versus the present, and the satisfaction received from working in agriculture. Moreover, irrigators have different approaches to making decisions. For example, most irrigators consider whether they should use allocations themselves or sell them on the market, yet some use allocations without considering the potential to sell them. The approach goes beyond simple gross margins analysis to capture the aggregate implications of these complexities for irrigated agriculture and water markets. For example, there are no assumptions that all irrigators within an industry are the same, or that irrigators are only motivated by financial considerations, or that irrigators always make optimal decisions. This is likely to lead to a better analysis and more robust conclusions. Further detail on the approach is provided in Section 3.2.
1.4 Structure of this report

The remainder of the report is structured as follows:

- Section 2 provides background on irrigated agriculture and water markets in the sMDB
- Section 3 outlines the conceptual framework and approach used in this assessment
- Section 4 draws on a database constructed from ABS and ABARES data to provide a broad statistical overview of recent trends in irrigated agriculture.
- Section 5 examines recent and future trends and drivers for the key industries listed above in greater detail through a series of case studies.
- Section 6 investigates the current demand for water allocations.
- Section 7 develops a scenario around future changes in demand for water allocations, and models the implications for water allocation prices and water use by industry. The overall gains from water trade are also estimated.
- Section 8 concludes by summarising the key findings, and briefly touching on some policy implications.
2. Background

The sMDB is an important irrigation area with Gross Value of Irrigated Agricultural Production (GVIAP)\(^1\) of almost $5 billion in 2013-14. Some regions were largely specialised in one or two irrigated activities, such as the Goulburn Broken, whereas others have a more even spread, such as the Murrumbidgee. The largest industry was dairy with GVIAP of around $1.6 billion (Figure 2). The main dairy regions were the Goulburn Broken and North Central in northern Victoria. Fruits and nuts were the second largest industry with GVIAP of around $1.2 billion, with the main regions being the Goulburn Broken, Mallee and SA MDB. The GVIAP of grapes was around $0.7 billion. The main regions for grapes were the Mallee and SA MDB. Rice and cotton were relatively small industries by GVIAP, and concentrated in the Murrumbidgee and Murray regions in southern New South Wales.

![Figure 2](image)

Source: Irrigated agriculture database, based on ABS and ABARES data.

### 2.1 Brief history of water markets

Current and future trends in irrigated agriculture in the sMDB are inexorably tied to water. This section provides a short background on the evolution of water markets in the sMDB to provide context for subsequent sections.

As early as the 1960s there were concerns around the potential for increasing volumes of diversions for irrigated agriculture in the sMDB to diminish the overall reliability of water for irrigation, as well as the potential for negative environmental impacts. To address these concerns, governments replaced area-based entitlements with volume-based entitlements and implemented embargoes on new water diversions between the late 1960s and early 1980s.

\(^1\) The gross value of irrigated agricultural production is the value of recorded production at wholesale market prices that is produced using irrigation water. It does not reflect the contribution of irrigation water to production.
As a result, irrigators who wanted to expand their operations and were unable to work around the rules had to buy water from other irrigators. As water was attached to land, irrigators would have to buy land and water together. In some cases the water entitlements could be amalgamated and transferred to other land under their ownership. The land could then be sold, sometimes back to the original owner.

The unbundling of land and water was intended to reduce the costs associated with this process. Water markets were first introduced in 1983, allowing for trade in water allocations within some regions. This was followed by trade in water entitlements within some regions, and eventually trade in both allocations and entitlements between regions.

While the embargos on new water diversions reduced growth in diversions, there was still an 8 per cent increase in diversions between 1984 and 1994. This was due to the activation of sleeper and dozer entitlements, access to supplementary water, and incomplete coverage of the embargoes. The MDB Cap was introduced in 1997 to limit future diversions to 1994 levels. Adjustments are made for wet and dry years (NWC 2011).

Water reform continued throughout the 1990s and 2000s. The National Water Initiative was signed in 2004, promoting interstate trade and a range of other market reforms (clarifying entitlements, further unbundling, compatible registers, and so on). There are now relatively mature markets for allocations and entitlements with relatively low transaction costs, high volumes of trade, and increasing use of related instruments such as forward contracts and entitlement leases to manage risk.

2.2 Recent trends in water markets

As discussed below, trends in water availability and markets have been a key driver of trends in irrigated agriculture. Water allocations to consumptive entitlements in the sMDB were highly variable between 1998-99 and 2014-15 (Figure 3). Water allocations to consumptive entitlements were high in the early 2000s, reaching a peak of 6 900 GL. This was followed by the millennium drought, which culminated in the two driest years on record with water allocations to consumptive entitlements of around 1 900 GL in the late 2000s. While inflows to storages recovered in the early 2010s, an increasing volume of water entitlements were reallocated to the environment through government buybacks. This had a significant effect. For example, although overall allocations in 2012-13 were similar to 2000-01, water allocations to consumptive entitlements were almost 1 000 GL lower due to reallocation. Water allocations to consumptive entitlements have been low thus far in 2015-16 (not shown in Figure 3) and water storages in the sMDB are currently at 40 per cent (MDBA 2016).

There was a strong negative correlation between water allocations to consumptive entitlements and water allocation prices. Aither’s peer reviewed statistical modelling of the allocation market indicates that there is also a strong negative causal relationship, with allocations prices being highly sensitive to changes in water allocations to consumptive entitlements, even when controlling for other variables that could influence allocation prices (Aither 2016).

Median annual water allocation prices peaked at around $540 per ML in 2006-07 with water allocations being traded from interruptible activities, such as rice, to maintain permanent plantings, such as fruits and nuts. A few years later, in 2011-12, water prices were around $20 per ML. In December 2015, water allocation prices were around $275 per ML, depending on the trading zone. There is weak evidence of an upward trend in median water allocation prices between 1998-99 and 2015-16, with water allocation prices increasing by around $1 per ML per year over that period. However, this trend disappears if 2015-16 is excluded.
Source: Aither water market data.

**Figure 3**  Total water allocations to consumptive and environmental entitlements and water allocation prices between 1998-99 and 2014-15
3. Framework and approach

3.1 Conceptual framework

The analysis in this report is organised around the following conceptual framework (Figure 4). The profitability of using land for an irrigation activity (such as cotton) depends positively on the prices of products generated by that activity and negatively on the prices of inputs required to undertake that activity (such as fertiliser). It also depends positively on production yields, which are governed by technology (such as crop varieties) and management practices (such as irrigation scheduling). The volume and timing of water applied also influences yields. Finally, the profitability (or attractiveness) of an activity depends on the individual preferences of the irrigator – including whether they enjoy undertaking the activity and their attitudes towards risk. Individual preferences are sometimes neglected in agricultural analysis, but are frequently important in explaining irrigators’ decisions.

Land use decisions also depend on the profitability of other activities. The profitability of an activity could be increasing in absolute terms, but if the profitability of an alternative activity is increasing faster land could move towards the alternative activity. It is relative profitability that matters.

Land use and water use are jointly determined – having more land makes it profitable to use more water, and having more water makes it profitable to use more land. Together, land use and water use determine production.

![Figure 4](image-url)  
**Figure 4** Stylised representation of enterprise production decisions for an activity

The production system outlined above is linked to markets, including the water market (Figure 5). The production system determines demand for water by individual irrigators. The interactions of buyers and sellers in the water market determines a price that more or less equates the total volume of water demanded (summed over all irrigators) with the total volume of water supplied at a point in time. The price is bid up if there is excess demand, whereas the price is bid down if there is excess supply. The price then feeds back to the production system, directly affecting water use and indirectly affecting land use decisions.
3.2 Approach

This report draws on multiple lines of evidence to better understand current and future trends in irrigated agriculture in the sMDB.

The first source of evidence is based on existing data collected by the Australian Bureau of Statistics (ABS) and the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) on recent trends. Examining these recent trends is relevant for understanding what might happen in the future. To make use of these data, a new database was constructed with adjustments to ensure consistency across multiple years and address missing values and data quality issues. The database was drawn on to visually illustrate recent trends across a range of variables. Statistical analysis was also used to estimate the direction and magnitude of recent trends, controlling for the effects of changes in seasonal conditions over the time series, which could otherwise bias estimates of the trends.

The second source of evidence addresses a limitation of the first, the potential to obscure important information on recent trends that are evident at a more disaggregated level. Case studies were developed for a number of key industries. These case studies were informed by evidence from various sources, such as stakeholder consultations, media reports and research papers. A qualitative narrative was developed for each case study with quantitative evidence being used wherever possible to provide additional evidence, and in particular, to resolve conflicting information from stakeholders.

In addition to examining recent trends, the case studies also address the drivers behind recent trends as well as possible future trends. Predicting the future is difficult – few would have anticipated five years ago that there would be a severe drought in California that would increase the price of almonds sufficiently to drive a boom in the sMDB. Yet the future is not entirely random, and it is possible and worthwhile to develop future scenarios around irrigated agriculture.

A number of simple modelling techniques were used to address different problems, including gross margin analysis to examine the determinants of profitability in the rice and cotton industries, and an analysis of land values to investigate expectations of future profitability in the grapes industry.
The third source of evidence is based on a mathematical model of the annual water allocation market in the sMDB. The model was developed to explore the implications of the future trends identified by stakeholders and outlined in the case studies. The model estimates (i) the changes in water allocation prices associated with projected changes in demand and (ii) the changes in water use by irrigated agricultural industries after accounting for changes in water allocation prices. The baseline demand for water was estimated for different irrigation industries and the environment drawing on evidence from multiple sources. The supply of water was based on a number of scenarios, reflecting different water availability conditions.
4. Recent trends in irrigated agriculture in the sMDB: a statistical overview

This section draws on a database constructed from ABS and ABARES data to provide a broad statistical overview of recent aggregate trends in irrigated agriculture in the sMDB. The following variables are considered:

- number of agricultural businesses irrigating
- land used for irrigation
- water used for irrigation, including water source
- gross value of irrigated agricultural production
- profitability.

These variables are illustrated visually and examined using statistical techniques. The more advanced statistical techniques provide a rigorous way of estimating year-to-year variability and medium term trends (Appendix A).

This section is deliberately aggregated and has the potential to obscure important information on recent trends that are evident at a more disaggregated level. Further detail on key individual industries is provided in Section 5.

4.1 Constructing the database

Aither has constructed an irrigated agriculture database to obtain an aggregate understanding of recent trends in irrigated agriculture in the sMDB. The database is primarily based on data from various Australian Bureau of Statistics (ABS) and Australian Bureau of Agricultural and Resource Economics and Science (ABARES) publications. The data were compiled to create a time series from 2005-06 to 2013-14. Adjustments were made to account for inflation, ensuring that financial variables are comparable across years.

A number of checks were undertaken to identify potential errors and missing values, with available information being used to impute these values. In particular, there were numerous instances in which the recorded volume of irrigation water applied was positive but the recorded area of land irrigated was zero, or vice versa. For example, the recorded volume of water used to irrigate cotton in the Murrumbidgee in a given year could be 80 GL, and the recorded area of land irrigated zero. To resolve this, information on water use per hectare from other years would be used to impute a value for the area of land irrigated, addressing the inconsistency. At 8 ML/hectare, the imputed area of land irrigated would be 10 000 hectares.²

The data were also crosschecked against data from other sources where possible. The data sources generally appeared to be consistent, nevertheless, there were some discrepancies for cotton and dairy. Water use for irrigation by region tended to be substantially lower in the ABS data than irrigation diversions in the Murray-Darling Basin Authority (MDBA) Water Audit Monitoring Reports, especially for the NSW Murray and Victoria. This could be due to losses within irrigation districts that

² This approach assumes that the non-zero value (water use in this example) is correct.
influence irrigation diversions as reported by the MDBA but not on farm water use as estimated by the ABS. ABS water use data were similar to data provided by the Victorian government.

Overall, Aither considers that the key data used in this section is suitable for the purposes of this assessment. However, there is the potential for unidentified errors in the source data and these would be carried into the database and the figures generated from the database.

### 4.2 Number of agricultural businesses irrigating

The number of agricultural businesses irrigating in a given year reflects the number of businesses in the irrigation industry as well as the proportion of those businesses that decide to irrigate in that year, recognising that some agricultural businesses irrigate opportunistically.

Between 2005-06 and 2013-14, there was an average of 11 400 agricultural businesses irrigating in the sMDB according to ABS data (Figure 6). The regions with the largest number of agricultural businesses irrigating were Goulburn-Broken (2 600) and SA MDB (2 000).

Year-to-year variability in the number of agricultural businesses irrigating was relatively high in the Wimmera and Murray regions. This reflects a relatively high concentration of irrigation activities that can be interrupted when seasonal conditions are unfavourable, such as pasture and cereals. Elsewhere, year-to-year variability in the number of agricultural businesses irrigating was moderated by a relatively high concentration of irrigation activities that cannot be interrupted when seasonal conditions are unfavourable without incurring significant expense. This is particularly evident in the Mallee and SA MDB, where permanent horticultural plantings can incur substantial long term damage if water is not applied every year.

Across the sMDB there has been a downward trend in the number of agricultural businesses irrigating of around 4.0 per cent per year, adjusting for seasonal conditions. The regions with the largest declines in percentage terms are North East Victoria (-6.6 per cent per year), Mallee (-5.1 per cent per year) and SA MDB (-5.0 per cent per year). By contrast, there was a small positive but statistically insignificant trend for the Wimmera. These trends are consistent with the amalgamation of irrigation businesses, with fewer businesses operating a similar area of irrigated land.
4.3 Land used for irrigation

From 2005-06 to 2013-14, an average of 820 000 hectares of land was used for irrigation in the sMDB (Figure 7). Dairy was the largest activity (420 000 hectares), followed by grapes (80 000 hectares) and fruits and nuts (60 000 hectares). A substantial area of land is also used for other irrigation activities. These include:

- cereals for grain and seed (excluding rice)
- other broadacre crops
- vegetables and
- nurseries, cut flowers and cultivated turf.

The averages mask substantial year-to-year variability for some activities. As expected, rice and cotton were the most variable activities. This was most evident in 2007-08 when there was almost no rice production in the sMDB. Fruits and nuts and grapes were least variable activities. These findings largely reflect the extent to which the activities are interruptible (discussed above), which substantially affects how responsive land use is in the short run to changes in water allocation availability and price.

Controlling for the impact of seasonal conditions, the total area of land irrigated followed a neutral trend. There were substantial positive trends for cotton (see Section 5.5) and fruits and nuts (2.7 per cent per year). As discussed in Section 5, much of the growth in irrigated agriculture is occurring on greenfield sites outside existing irrigation districts. There were large negative trends for grapes (-3.1 per cent per year) and dairy (-2.6 per cent per year).
4.4 Water used for irrigation

The previous section examined land used for irrigation over time. There tends to be a strong relationship between water and land use for the industries considered, with water application rates largely stable between 2005-06 and 2013-14 (Figure 8). The exception was 2010-11 when there was a noticeable reduction in water application rates across all of the industries considered due to high water prices. Fruits and nuts has experienced a dramatic increase in water application rates since 2010-11. As explained more fully in section 5, this is principally driven by the almond industry, which uses substantially more water per hectare than fruits. As a result, the expansion in almonds led to a surge in the share of almonds in overall fruits and nuts, and an increase in average water application rates. Overall, there is no clear evidence at the aggregate level that investments in water use efficiency technology have substantially reduced water application rates.

Average water application rates differ markedly between activities, with rice (12 ML per hectare) and cotton (8 ML per hectare) having the highest application rates. Dairy had the lowest estimated application rate (3 ML per hectare). The estimated water application rate for dairy appears to be too low when compared with other sources of information. According to DPI (2011), water application rates in dairy are about 8 ML per hectare for perennial pasture and about 4 ML per hectare for annual pastures in average rainfall years. This is consistent with Dairy Farm Monitor survey data, which suggests average water use (including rainfall) was around 9.5 ML per hectare in northern Victoria between 2011-12 and 2014-15. For context, long term average rainfall was around 4.5 ML per hectare.
Over the years considered, average water use for irrigation in the sMDB was around 3 350 GL per year (Figure 9). This is below the long term average due to the prevalence of drought years. The largest user of water was dairy (1 260 GL), followed by rice (660 GL) and fruits and nuts (410 GL). Rice was more prominent in water use than land use because of its relatively high water application rates.

Water use was more variable than land use for most activities, with the main exception being rice. The trends in water use broadly mirror trends in land use. Controlling for the impact of seasonal conditions, there were substantial positive trends in water use for cotton (growth rate not defined) and fruits and nuts (8.0 per cent per year). There were large negative trends for dairy (-5.8 per cent per year) and grapes (-3.9 per cent per year).

The water use estimates outlined above exclude rainfall. Rainfall is a major source of water for irrigated agriculture in the sMDB. Based on the average annual rainfall for the entire MDB (including the north) of around 470 mm per year and average irrigated land use of around 820 000 hectares, around 3 900 GL per year of rain would fall on irrigated land in the sMDB. This is similar to the volume of water used for irrigation. In practice, a ML of rainfall is typically far less beneficial than a ML of irrigation water, since the timing of rainfall cannot be controlled.
Between 2005-06 and 2013-14, the largest source of irrigation water in the sMDB was irrigation systems (2 300 GL per year), followed by on-farm dams and rivers (780 GL) and groundwater (440 GL) (Figure 10). Only six years of data were available. The small sample size makes it difficult to draw reliable inferences regarding variability and trends in water use by source. Hence, the statistical analysis reported in the appendix should be interpreted with caution.

The countercyclical use of groundwater is evident in the data. Groundwater use was higher in the first three years of the sample, which corresponded to drought years, than the final three years of the sample. This is because groundwater is expensive to pump, with the costs depending on the depth of the water table. Irrigators with access to surface water will typically only substitute to groundwater when water allocation prices are high.
4.5 Gross value of irrigated agricultural production

GVIAP depends on the area of land irrigated and the gross value per hectare irrigated. Gross value per hectare irrigated can vary substantially from year to year depending on yields, commodity prices received by irrigators, and the composition of activities in each of the broad categories. Between 2005-06 and 2013-14, dairy and grapes were the most variable in terms of gross value per hectare irrigated, while cotton and fruits and nuts were the least variable according to ABS data (Figure 11).

Average gross value per hectare irrigated was highest for fruits and nuts ($18 300 per hectare) and grapes ($9 200 per hectare), and lowest for dairy ($3 500 per hectare) and rice ($4 000 per hectare). The only major trend was an increase in gross value per hectare irrigated for cotton (5.2 per cent per year).

Over the years considered, average GVIAP in the sMDB was around $3.8 billion per year (Figure 12). The activities with the highest average GVIAP were dairy ($1.4 billion) and fruits and nuts ($1.0 billion).

The year-to-year variability in GVIAP was slightly lower than for land use, but followed a similar pattern across activities. The adjusted trend in GVIAP was positive for cotton (growth rate not defined) and fruits and nuts (1.7 per cent per year), and negative for dairy (-2.8 per cent per year) and grapes (-2.2 per cent per year).
Figure 11  Gross value per hectare irrigated by activity in the sMDB – 2005-06 to 2013-14

Figure 12  Gross value of irrigated agricultural production by activity in the sMDB – 2005-06 to 2013-14
4.6 Profitability of agricultural businesses irrigating

The average profitability of agricultural businesses irrigating in the sMDB was low between 2006-07 and 2011-12 according to ABARES data (Table 1). This is unsurprising given low water availability and high water allocation prices in many of these years. There would be value in extending the time series, but more recent data were unavailable. The case studies presented in the next section show that profitability has subsequently improved for many industries.

There were no substantial differences in average profitability between horticulture, broadacre and dairy. Average farm cash income was around $75 000 per year. Accounting for changes in trading stocks, depreciation and imputed labour, average farm business profit was negative at around -$10 000 per year. The rate of return considers rent, interest and leases and is expressed relative to operating capital. The average rate of return was around 1 per cent per year. This is substantially less than most alternative investments. However, these are average returns and some agricultural businesses have been highly profitable. The profitability of individual industries is discussed in further detail in Section 5.

Table 1  Average profitability of agricultural businesses irrigating in the sMDB – 2006-07 to 2011-12

<table>
<thead>
<tr>
<th></th>
<th>Horticulture</th>
<th>Broadacre</th>
<th>Dairy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm cash income ($ per farm, 2013-14 dollars)</td>
<td>63,752</td>
<td>77,060</td>
<td>85,750</td>
</tr>
<tr>
<td>Farm business profit ($ per farm, 2013-14 dollars)</td>
<td>-3,884</td>
<td>-15,153</td>
<td>-7,310</td>
</tr>
<tr>
<td>Rate of return (%)</td>
<td>1.2</td>
<td>0.7</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Source: Irrigated agriculture database, based on ABS and ABARES data.
5. Recent trends and expectations in irrigated agriculture in the sMDB: industry case studies

This section extends Section 4 by considering the factors driving recent trends as well as future trends. The following industries were selected for detailed case studies:

- wine grapes
- almonds
- rice
- cotton
- dairy.

These are large industries that are important in shaping the demand for water. Walnuts are also discussed, but in less detail.

5.1 Wine grapes

There are three broad types of grape production in the sMDB – wine, table and dried – with specialised varieties typically used in each type of production. Some enterprises grow a combination of wine, table and dried grape varieties. Although wine grapes are grown throughout the sMDB, the largest plantings are in the South Australian MDB, Murrumbidgee and Mallee. The vast majority of wine grapes in the sMDB are irrigated.

Land use trends covering all types of grape production are discussed in the previous section. In terms of the production of wine grapes, there was a large expansion in the sMDB during the wine boom starting in the late 1980s. As wine grapes expanded they replaced other activities such as citrus and became the dominant irrigation activity in some regions. In the Murray Valley, the overall production of wine grapes increased slightly over the last decade from 396 000 tonnes in 2004 to 414 000 tonnes in 2014 (MVWI 2015a). In the Riverina, production increased from around 220 000 tonnes in 2004 to around 300 000 tonnes in 2013 (RWGMB 2015).^3

Key determinants of recent profitability

Product prices

Stakeholders identified product prices as the most important long term driver of wine grape production. Between 2004 and 2014 the average producer price of wine grapes in the Murray Valley fell from $570 per tonne to $310 per tonne (without adjusting for inflation). The decline was more dramatic for some varieties than others. In particular, the producer price of Chardonnay, which accounts for around 30 per cent of land used for wine grapes in the Murray Valley, fell dramatically from $881 per tonne to $216 per tonne. Prices remained relatively high for some varieties, with the producer price of Pinot Gris at around $480 per tonne in 2014 (MVWI 2015a).

^3 These trends are broadly consistent with data from the Australian Grape and Wine Industry Database (https://www.adelaide.edu.au/wine-econ/databases/winehistory/).
Input prices

The major input cost in the production of wine grapes is labour. In the Murray Valley in 2014, owner and hired labour accounted for around 28 per cent of costs (Retallack 2015). Water and electricity are also important input costs, with substantial electricity costs associated with pumping and filtering water in many regions. Electricity prices have recently increased substantially in the Riverland due in part to higher network charges (ABC 2014a). According to the Central Irrigation Trust, the electricity bill for their largest pumping station increased by 67 per cent from 2010 to 2015, although it is unclear how much of this increase is attributable to changes in the volume pumped (ABC 2015a).

Recent profitability

Declining product prices and increased input prices have contributed to a reduction in the profitability of wine grape production. In the Murray Valley, average revenue has fallen from around $17 000 per hectare in 2004 to $7 000 per hectare in 2014. When operating and overhead costs are considered, average profit was negative in each of the last three years surveyed (2009, 2011 and 2014).

There was substantial variability in profit in 2014, with the bottom 10 per cent losing in excess of $6 000 per hectare and the top 10 per cent gaining in excess of $2 000 per hectare. Some of these differences are due to the varieties planted (MVWI 2015b).

There were conflicting views among stakeholders regarding the importance of size as a determinant of relative profitability. On balance, stakeholders in the wine grape industry thought there were some advantages in size up to 50 hectares, but limited advantages thereafter. Size is not sufficient to guarantee profitability, with the Littore Wine Group, which owns 1 800 hectares of vineyards near Mildura, being placed into receivership in late 2015 (Geelong Advertiser 2015).

Land use response to recent profitability

There has been some land use change in response to falling profitability. This is evident in the ABS statistics mentioned above which show an underlying decrease in the area of grapes (of all types) irrigated. This trend has been confirmed by stakeholders across the wine grape growing regions. For example, in the Riverland, over 200 growers have removed their vines in the last five years (ABC 2015c).

Yet, as outlined above, the change in land use has not been rapid enough to cause production to decline. This reflects a judgement by most growers that, in the short term at least, the returns from their established wine grape plantings will exceed the returns from redirecting their resources – land, water and labour – to other feasible activities.

Alternative agricultural activities that wine grape growers have switched to include almonds, table grapes, watermelons, avocados, zucchinis, cucumbers, pumpkins, mangoes, citrus, flowers and turf. Stakeholders argued that the returns to land and labour in other activities are often limited. Various factors including soil and climate (frost, wind and so on) limit the extent to which some land used to grow wine grapes can be redeployed to other activities. Even if the land is suitable, wine grapes are often grown on relatively small blocks, which are potentially difficult to amalgamate, particularly in...
This limits the value of such land in alternative activities, such as almonds, where there are substantial economies of size. Other factors, such as an irrigation layout designed around wine grapes, can also reduce the value of land in alternative activities. The labour of some wine grape growers could also have limited value in alternative activities. A high proportion of growers are nearing retirement age and may have limited interest in acquiring the skills necessary to move into alternative agricultural activities. Many also value the lifestyle of growing wine grapes. Together, this suggests that the movement away from growing wine grapes is limited, in part, because the alternatives available to growers have limited appeal.

Stakeholders also stressed the importance of debt. In some instances wine grape growers may have drawn down their equity to the extent that their capacity to borrow in order to invest in establishing new crops is limited. This is a potential issue for alternative agricultural activities than require substantial upfront capital expenditure.

In the long term, the costs of any major reinvestments, such as upgrading irrigation systems or establishing new wine grape varieties, are also considered and land use change is more likely to occur. The dynamics discussed in this section explain why there are typically longer lags in adjustments to changes in profitability for activities such as wine grapes than for annual cropping activities. It is also consistent with the stakeholder observations that there has been little investment in maintenance in many vineyards, leading to broken posts and leaking drippers.

### Expectations for the future

Most stakeholders expected the area of wine grapes in their regions to continue to decline at a similar rate over the next five years as irrigators gradually respond to reduced profitability. The projections are subject to uncertainty. Anything that reduces profitability relative to expectations could increase the rate of change, and vice versa. For example, if the current drought continues for longer than expected, this would increase the probability of the area of wine grapes falling more than expected.

At the level of individual growers, some who are hanging on despite low profitability could exit the industry due to retirement or because their vineyards require major reinvestments. There is a distinction between individual growers exiting the industry and land exiting the industry, since individual growers can sell their vineyards to other growers who might continue to produce wine grapes, if profitable. However, these issues are also related since individual growers provide a cheap supply of owner labour to the industry.

Expectations regarding future profitability are also reflected in land values, with higher land values reflecting greater optimism. Aither conducted an analysis of land values for established wine grape vineyards in the Sunraysia region. Typical land values were $12,000 per hectare to $20,000 per hectare. This is below the cost of establishing a vineyard, and not substantially above the typical value of vacant irrigable land of about $9,000 per hectare.

Stakeholders revealed that expectations would be more pessimistic if not for:

- the free trade agreement with China, which will eliminate tariffs on Australian wine imports within four years. For context, tariffs on Australian wine are currently between 14 to 20 per cent.
- the depreciation of the Australian dollar, which increases demand for Australian wine exports and, by implication, Australian wine grapes.
- any increase in producer prices if the supply of wine grapes falls.

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4 Land with houses were excluded from the sample. Land with water rights were included, but the estimated value of water rights was subtracted for the total. The values were checked with stakeholders to ensure plausibility.
5.2 Almonds

The main regions for almond production in the sMDB are the Sunraysia (67 per cent of national production), Riverland (19 per cent) and Riverina (11 per cent). All commercial almond production in the sMDB is irrigated.

There have been two major expansions in the almond industry in the sMDB over the last two decades. The first boom started around 2001 and ended around 2007, with the total area of land planted to almonds increasing from 5 000 hectares to 26 000 hectares over that period. The expansion of the industry then slowed. The total area of land used in almond production was around 29 000 hectares in 2014. As the almonds trees from the first boom have matured, almond production has increased (Figure 13). Almond trees take 6 to 8 years to reach full maturity, so there is unlikely to be any further increase in production from almonds planted during the first boom. A second boom may have just commenced with major investments underway and in the pipeline, although the recent decline in almond prices could deter some investment. The implications of these investments are discussed in more detail subsequently.

Figure 13 Annual almond planting and production in Australia

Key determinants of recent profitability

Product prices

Almond prices were identified by stakeholders as the main driver of investment in the almond industry. World almond prices more than halved between 2005 and 2008, with the price decline coinciding with the end of the first boom (Hilltop Ranch 2012). Australian almond prices increased from around $6 per kilogram between 2008 and 2012 to in excess of $13 per kilogram in late 2015 (Figure 14, all prices expressed in 2014 dollars). This dramatic increase in price was a result of the Californian drought. Californian growers account for around 75 per cent of the global supply of

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5 These are national figures, however, around 97 per cent of Australian almond production takes place in the sMDB.
almonds. As a result of the prolonged drought, Californian production declined from a peak of around 920,000 tonnes in 2012 to 750,000 tonnes in 2015, resulting in higher prices (Almond Board of Australia 2015). Australian growers also benefited from the recent depreciation of the Australian dollar. Californian production has recently recovered, prompting a fall in almond prices.

Note: Data not available for earlier years or early 2016.
Source: Almond Board of Australia (2015).

**Figure 14 Average price of Australian almond exports (2014 dollars)**

**Recent profitability**

The mechanism by which almond prices influence land use decisions is through profitability. Almond production was highly profitable in 2015. Typical revenue was around $35,000 per hectare from mature trees, whereas typical operating costs are around $10,000 per hectare.

The share price of Select Harvests, one of the largest almond producers in the sMDB, reflects the changing fortunes of the industry over the last decade. In 2006, towards the end of the last almond boom, the share price was above $13. In 2012, just before the recent uplift in almond prices, the share price was about $1. It has since recovered to around $5 (ASX 2016).

**Land use response to recent profitability**

Similar to wine grapes, adjustments to land use in response to changes in recent profitability have been lagged. Asset fixity limited the adjustment to low profitability between 2007 and 2012, while the response to high profitability has also been delayed.

Most new almond developments are on greenfield sites. This gives owners more flexibility to develop their irrigation systems around almonds and exploit the economies of size in almond production. Even after the decision to establish new almond trees has been made and necessary finance organised, there can be lengthy delays associated with obtaining regulatory approvals, building water infrastructure and planting the almond trees. Similar issues arise for almond developments on existing irrigation sites, except that any existing plantings must be removed and water infrastructure must be retrofitted for almond trees, which tend to use more water than other irrigation activities.

There is a limited amount of land that is suitable for almond production, which effectively constrains the area of land that can be profitably planted to almonds. In particular, almonds require favourable
soils and climates, access to reliable irrigation water (which makes development further than 7km from rivers very expensive in terms of pumping, and restricts development on some rivers), and, ideally, large blocks. Stakeholders thought that it would be possible to grow almonds on small blocks. However, this would probably require small growers to share or lease machinery, which is not necessarily a popular option.

Large investors have helped to fuel the expansion in the almond industry. The use of heavy machinery in the almond industry means that large areas can be profitably managed by a relatively small number of people. This is attractive to investors. The first boom was financed in part through the managed investment schemes. Recently, some investment is originating from overseas, with United States and Canadian pension funds who have invested in Californian almond plantings seeking to diversify their portfolios (AFR 2015).

**Expectations for the future**

The almond industry could expand substantially over the next five years, with the Almond Board projecting 15 000 hectares of new plantings in the sMDB (Mildura Weekly 2015). Major developments are planned for the Riverland and Sunraysia regions, as well as the Murrumbidgee. The extent to which the recent decline in almond prices constrains these developments remains to be seen.

These investments are largely motivated by optimism regarding almond prices in the medium term. While Californian production is recovering, Californian growers face a number of long term challenges relating to groundwater depletion, land subsidence and salinity. According to the Almond Board, almond prices could settle at around $8 per kilogram in the long run.

5.3 Walnuts

There are currently around 2 000 hectares of walnut trees in the sMDB, mostly in the Riverina. Outside the sMDB, there are around 500 hectares in Tasmania. Australia is a small supplier in the global walnut market with output of around 12 000 tonnes per year. By contrast, China produces around 600 000 tonnes per year and California producers around 470 000 tonnes per year (ABC 2014b). Australia and Chile, another southern hemisphere supplier, have an advantage in being able to supply fresh walnuts in the counter season to the major northern hemisphere suppliers.

Around 90 per cent Australian production is supplied by Webster Limited within a vertically integrated operation. Webster recently built a walnut cracking plant in Leeton and has increased sales to the domestic market in partnership with a major retailer.

Australian walnut prices increased substantially until last year, caused by growth in global walnut prices and the depreciation of the Australian dollar. However, global walnut prices have since fallen as a result of higher production in China and California. Although affected by drought, Californian walnut producers have generally retained better access to irrigation water than Californian almond producers, who tend to be further south and have less access to groundwater.

Producing walnuts in the sMDB is currently profitable. This is reflected in high prices for established walnut trees.

**Expectations for the future**

Webster’s recent acquisitions of Tandou and other agricultural enterprises have resulted in substantial holdings of land and water resources. While these purchases are partly motivated by diversification into other activities such as cotton, some of these resources will be available to expand their walnut business. The main constraint on this expansion is the capacity of Webster’s nursery, which is able to
grow enough trees to plant around 500 hectares per year. Stakeholders said that they expected the nursery to operate at full capacity over the next five years, meaning an additional 2,500 hectares of planting.

Yields in the Riverina have been negatively affected by high temperatures and extreme winds during pollination in the last two years. It is possible that some of this future development could occur further south where temperatures are cooler, potentially in northern Victoria.

5.4 Rice

The Murray and Murrumbidgee regions account for over 99 per cent of rice production in the sMDB (ABS 2015). All rice grown in the sMDB is irrigated.

Land use trends for the rice industry are discussed in the previous section. In terms of production, there have been noticeable long term trends, despite year to year variability. Rice production went through a period of expansion between the mid 1980s and early 2000s, with production doubling to around 1.2 million tonnes. During the millennium drought rice production fell as low 20,000 tonnes in 2008 (Figure 15). Production rebounded after the millennium drought to around 1.1 million tonnes in 2013 but has subsequently fallen to around 0.7 million tonnes. Production estimates for the 2016 crop are commercial in confidence. Nevertheless, stakeholders confirmed that rice production will fall dramatically relative to recent years.

Source: SunRice annual reports and Aither water market data.

Figure 15 Rice production and prices in the sMDB, 2006 to 2015

Key determinants of recent profitability

In addition to water allocation prices, discussed in Section 2.2, there have been a number of other important drivers of recent profitability.

Producer prices

In the sMDB, most rice is sold through a pool system whereby all of SunRice’s profits from rice products are returned to growers through paddy rice prices. Since profits cannot be known in advance,
SunRice was typically unable to announce rice prices in advance. This exposed growers to financial risk, since prices were unknown when planting decisions were being made. SunRice departed from this approach in the millennium drought and again for the 2016 crop, by guaranteeing a price of $415 per tonne to encourage rice production.

SunRice produces a range of rice products, many of which involve considerable processing. The profits made from these products (excluding the cost of rice) are influenced by world rice prices, since a reduction in world rice prices could reduce prices of substitute rice products supplied by SunRice’s competitors, reducing demand for SunRice products. However, the relationship between profits and world rice prices is indirect and profits are shaped by numerous other factors, such as the marketing value of SunRice brands and processing costs. Hence, world rice prices do not necessarily provide a good indication of rice prices received by growers. Since most SunRice products are exported, currency exchange rates have a substantial effect on profits, and by implication, rice prices received by growers.

Paddy rice prices tend to be positively correlated with water prices, with higher prices in years with low water availability (Figure 15). Paddy prices increased from around $350 per tonne during the mid 2000s to around $600 per tonne in the late 2000s, and have subsequently returned to around $350 per tonne (all prices expressed in 2014 dollars).

**Gross margin analysis**

Gross margins can be used to obtain a broad sense of the relationship between producer prices, water allocation prices and profitability. The analysis draws on some parameters from Booth Associates (2015).

Figure 16 shows that higher water prices have a substantial negative effect on profitability. This is because water is a major input into the production of rice, with growers typically applying between 10 and 14 ML per hectare depending on whether they use drill or aerial sowing, and whether they are in the Murray or Murrumbidgee.

Higher paddy rice prices have a large positive effect on profitability. Figure 16 illustrates the relationship between water allocation prices and profitability for two different producer prices, corresponding to 2013 and 2014. In terms of profitability, the $93 per tonne increase in producer prices between 2013 and 2014 was equivalent to an $80 per ML decrease in the water allocation price.

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6 This type of analysis has a number of limitations. For example, it does not allow for flexibility in the production system to adjust input use per hectare in response to changing prices. It does not capture the risk and uncertainty involved in agricultural production. It also does not model profitability in the context of realistic cropping systems where crops are rotated. While these issues can be addressed, it is beyond the scope of this project.
Recent profitability

The average profitability of rice growers in the sMDB moved in line with water availability, with low profitability towards the end of the millennium drought followed by relatively high profitability (Figure 17). In the high profitability years, average cash income was around $180,000 per farm per year, while the rate of return on capital was around 3 per cent.
Land use response to recent profitability

Without major specialised investments and permanent plantings, land use tends to adjust relatively quickly to changes in relative profitability in the rice industry. For example, the machinery and irrigation layout required for rice is the same as for winter cropping. This enables rice growers to opportunistically move between activities. This is consistent with the ABS statistics, which shows that the rice industry has the greatest year to year variability in land use of the industries considered.

However, there are still lags in the system as evidenced by the time taken for rice production to return after the millennium drought broke (Figure 15). Rice production was just 0.7 million tonnes in 2011 despite the median water allocation price being $37 per ML. Rice production increased to 1.2 million tonnes in 2013, with no decrease in the median water allocation price or increase in the rice price relative to 2011. In part, the delayed adjustment was due to limited maintenance of irrigation infrastructure during the drought.

As in other industries, land use change depends not only on absolute profitability but the relative profitability of alternative land uses. Rice growers in the sMDB have always had alternative summer crops, such as maize and soybeans. However, rice remained dominant until the absolute profitability of cotton increased in the Murrumbidgee. The profitability of cotton in the Murrumbidgee is largely due to the development of shorter growing season varieties. Given the cooler climate in the Murrumbidgee than traditional cotton growing areas in the northern Murray-Darling Basin, planting has to take place later in the season. With longer growing season varieties, the cotton crops would not necessarily be mature at harvest and yields and quality would suffer. Shorter growing season varieties largely address this issue, improving profitability. Cotton is less profitable in the Murray region where the climate is not as suitable as the Murrumbidgee, although a small number of farmers have experimented with cotton. These issues are discussed further in the Section 5.5.

All stakeholders agreed that cotton was generally more profitable than rice on a large scale (greater than 750 hectares) in the Murrumbidgee, and most rice growers that previously operated on this scale have shifted to cotton in recent years. Relative profitability is not as clear on a smaller scale, with disagreement among stakeholders. There is agreement that in isolation growing cotton tends to be more profitable than growing rice for small and medium landholders. Those associated with the rice industry argue that rice performs better in crop rotations, is easier to grow, and subject to less risk. There are also substantial upfront capital costs in transitioning from rice to cotton.

Stakeholders argued that the land use decisions of rice growers are complicated by a failure by some to account for the opportunity cost of allocations associated with their own entitlements. That is, some growers treat these allocations as free, which does not account for the possibility that allocations can be sold on the market. Others said this was true only of a small minority of growers.

This could be one reason why rice production in the Murray region is more variable than in the Murrumbidgee region. Growers in the Murrumbidgee typically have greater entitlement relative to their land. As a result, these growers typically have more water that could be perceived as being costless to use, which could lead to higher production in years with high water prices. This could be exacerbated by the fact that allocations are typically made available later in the season in the Murray (see Aither water markets reports), which increases the risks associated with planting.

Expectations for the future

Stakeholders expected to see a slight decline in the industry over the medium term. However, there could be a larger decline if underlying water prices increase substantially (abstracting from year-to-year variation). The rice industry’s prospects depend in part on whether the small and medium landholders in the Murrumbidgee find it profitable to move into cotton.
It also depends on what happens to the rice processing industry. There are three rice mills in the sMDB. The Coleambally mill is currently mothballed, and could be converted to process other agricultural commodities (Stock Journal 2014). While rice growers might be able to remain viable while occasionally engaging in rice production, SunRice requires a reliable source of rice to supply its customers. During the millennium drought, SunRice sourced rice from overseas. The company is also expanding into Northern Australia, having recently acquired a processing plant in the Burdekin region. If the proposed public listing of SunRice is approved by shareholders, this would give SunRice access to additional sources of capital to finance expansions into other regions, although there are no immediate plans to do so (SMH 2015).

Like other industries, the future of the rice industry will be influenced by the development of new technologies. The industry hopes that shorter growing season varieties will increase the attractiveness of rice by increasing the potential to rotate between winter crops and rice.

### 5.5 Cotton

The Murrumbidgee region accounts for the bulk of cotton production in the sMDB, although there is limited production in the Murray region. All cotton produced in the sMDB is irrigated.

There has been irrigated cotton production in the northern MDB since the 1960s, but until 2011 there was very little cotton production in the sMDB. Since then, the area of land used for cotton production has increased to around 43 000 hectares (Figure 18). This is between 7 and 22 per cent of national land used for cotton production, depending on the seasonal conditions (ABARES 2015).

There are some discrepancies in land use estimates between data sourced from the ABS and data provided by Monsanto, who is a supplier of cotton seed. In particular, the ABS numbers appear to understate the recent expansion of the cotton industry. ABS land use estimates are used in Section 4 for consistency with the other variables examined. Monsanto estimates are used in this section.
Key determinants of recent profitability

In addition to water allocation prices, discussed above for rice, there have been a number of other important drivers of recent profitability.

Yields

Stakeholders identified improved yields as an important driver of profitability in the sMDB (and the land use trends illustrated above). Nationally, yields have increased from around 7.5 bales per hectare in 2002 to around 10 bales per hectare in 2014 (Cotton Australia 2015). Yields in the sMDB were around 12 to 13 bales per hectare in 2015, albeit under favourable conditions.

The key reason behind improved yields in the sMDB is the development of new genetically modified cotton varieties. As discussed above, the growing season is shorter in the Murrumbidgee than further north, and this substantially reduces yields and quality from traditional varieties. This has been largely addressed through the development of varieties adapted to shorter growing seasons. Further increases in profitability have been made through the development of varieties that are tolerant of herbicides and resistant to pests such as the heliothis moth. These new varieties have been accompanied by advances in agronomy and management techniques.

Producer prices

Improvements in global yields have contributed towards a slow but steady decline in real cotton prices received by Australian growers since 1990, with prices currently around $500 a bale (Figure 18, all prices expressed in 2014 dollars).

Unlike rice growers, cotton growers have the ability to forward sell future production. This has the potential to reduce risk. However, some growers are wary about entering into long term forward contracts in drought conditions when future water allocation prices could be high.
Gross margin analysis

Aither used a similar approach as discussed above for the rice industry to explore the sensitivity of profitability to changes in water allocation prices and yields (Figure 19). The same general caveats apply (see section 5.4).

Higher water allocation prices have a negative effect on the profitability of cotton production, but the effect is less pronounced than for rice production since water application rates tend to be lower for cotton. Typical cotton growers use around 9 ML per hectare in the sMDB.

Higher yields have a substantial positive effect on profitability. Figure 19 illustrates the relationship between water allocation prices and profitability for two different yields. The first is based on the national cotton yield in 2002 of 7.5 bales per hectare. The second is based on the sMDB cotton yield in 2015 of 12.0 bales per hectare. In estimating these curves, all other variables are held constant. For perspective, the 4.5 bales per hectare increase in yields over the period considered is equivalent to a $230 per ML decrease in the water allocation price. The magnitude of this effect helps to explain the recent expansion of the industry into the sMDB. This yield differential is not intended to reflect typical annual variability in yields.

![Figure 19 Key determinants of profitability for a typical cotton grower](image)


Recent profitability

Data on the profitability of cotton growers was available for the entire MDB, but not disaggregated to the sMDB. Cotton production has been highly profitable, on average, in the entire MDB since cotton became a substantial industry in the sMDB (Figure 20). Average cash income was around $570 000 per farm per year between 2010-11 and 2014-15 (in 2014 dollars). Some of this reflects the large scale of many cotton enterprises, yet there were also high average rates of return by the standards of most agricultural industries at around 6 per cent.
Land use response to recent profitability

While there are costs in redeploying land to cotton production, such as specialised machinery and irrigation layouts, land use change has been rapid in response to the increasing attractiveness of growing cotton. Existing landholders in the sMDB have often experimented with cotton for a season before moving additional land into cotton production. At the same time, large cotton growers have expanded their operations from the north, attracted by the relatively low cost and greater reliability of supply of water in the Murrumbidgee River system.

Expectations for the future

Stakeholders expect the cotton industry in the sMDB to continue to expand over the medium term, with some expecting production to double in the next few years. Some investment is expected to flow from cotton growers in the north, where there is higher rainfall during the growing season but less reliable, higher cost irrigation water. The availability of suitable land is unlikely to be a major impediment to this expansion. Some stakeholders argued that conditions for growing cotton in the sMDB have been unusually favourable over recent seasons, and the expansion of the industry could be moderated if there are unfavourable seasons resulting in reduced yields and quality.

There have recently been three major developments predicated on the success of the cotton industry in the sMDB – the Whitton gin (opened in 2012), the Hay gin (opened in 2015), and the Carrathool gin (under construction). Prior to 2012, cotton grown in the sMDB was hauled north at substantial expense. The combined capacity of these gins is around 600 000 bales per year. Assuming all production in the sMDB is directed to these gins, and yields are 11 bales per hectare, around 55 000 hectares would be required to meet capacity. If throughput must be at least 70 per cent of capacity to maintain profitability, an average of 38 000 hectares would need to be directed to cotton production. Given that around 43 000 hectares were planted in 2015, the industry is likely large enough to sustain these gins without much further expansion.
5.6 Dairy

The largest dairy areas in the sMDB are the North Central, Goulburn Broken (in northern Victoria) and the Murray (in southern New South Wales). Most dairy farmers in the sMDB irrigate pastures or cereal crops, generally within public irrigation districts. Around 75 per cent of land used to irrigate pastures or cereal crops is used for grazing, with the remainder used for hay and silage. Some dairy farmers have access to both groundwater and surface water. However, pumping groundwater can be expensive, around $70 per ML, and slow. As a result, groundwater is typically only used when water allocation prices are high.

As discussed in the previous section, the area of land irrigated for dairy was highly variable, with the area more than doubling from around 225 000 hectares towards the end of the drought in 2008-09 to around 545 000 in 2013-14. Milk production is much less variable, increasing from 160 000 to 190 000 kg MS per farm over the same period in northern Victoria (Figure 21). This potential divergence between input use (on farm) and production is created by the ability to source feed externally, and represents an important difference between dairy and the other industries examined in these case studies.

Note: The small sample size means that production and milk price estimates are only indicative of broader trends. Moreover, the survey results used to generate this figure only capture farms in northern Victoria. Hence results do not reflect changes in production or milk prices for dairy in other parts of the sMDB. Finally, the measure of production used is an average per farm, and does not reflect changes in production due to changes in the number of farms.

Source: Dairy Australia Farm Monitor reports (various years) and Aither water market data.

Figure 21 Average dairy production and milk prices in northern Victoria, 2007-08 to 2014-15

Key determinants of recent profitability

In addition to water allocation prices, discussed in Section 2.2, there have been a number of other important drivers of recent profitability.

Producer prices

Milk prices received by dairy farmers in northern Victoria varied substantially over the period examined, although some of this variability is disguised by the logarithmic scale used in Figure 21.
Milk prices were around $7.70 per kg MS in 2007-08, subsequently falling to around $5.00 per kg MS in 2009-10. Milk price had recovered to around $6.00 per kg MS by 2014-15 (all values expressed in 2014 dollars). These changes in milk prices received have been primarily driven by changes in world prices and exchange rates.

**Feed prices**

Dairy feed prices in northern Victoria are positively correlated with water allocation prices, with real feed prices being around $380 per tonne DM during 2007-08, and falling to around $250 per tonne DM as seasonal conditions improved (Figure 22). Feed prices subsequently increased to around $340 per tonne DM in 2014-15. This pattern arises because there is higher demand for feed from dairy and other livestock industries during drought. The supply of feed can also be negatively affected by drought, although supply can increase if there are failed crops.

Note: See caveats for Figure 21.

Source: Dairy Australia farm Monitor reports (various years) and Aither water market data.

**Figure 22 Dairy feed prices in northern Victoria, 2007-08 to 2014-15**

**Production technology and management practices**

The millennium drought promoted considerable innovation in the sMDB dairy industry. Some enterprises did not survive the millennium drought, but many that did developed business plans based around lower water use intensity. Dairy farmers adopted irrigation technologies, such as centre pivot, that sometimes promote water and labour savings. Some of this investment was subsidised by government programs. Dairy farmers also lowered their use of irrigation water by growing and storing winter crops for summer, rather than irrigating during summer.

The relative stability in milk production compared with irrigated land use, noted above, is achieved by purchasing additional feed to compensate for declines in feed generated on farm during drought. Some stakeholders argued that the industry was moving towards a feedlot approach in the sMDB. This is not apparent for the relatively small number of farmers in northern Victoria surveyed for the Dairy Australia Farm Monitor reports, with the percentage of energy requirements of milking cows imported showing no upwards trend (Figure 23). Farmers continue to be creative in how they meet the feed requirements of their cows, with some including wasted confectionary into their feeding mix.
Recent profitability

According to the Dairy Australia Farm Monitor reports, average net income between 2007-08 and 2014-15 was around $110,000 per farm per year (Figure 24). This measure includes variable and overhead costs as well as interest and lease charges. There was substantial variability from year to year, with average net income as low as $-40,000 per farm per year in 2009-10 and as high as $300,000 per farm per year in 2013-14.

Many dairy farmers sold water entitlements to the Commonwealth during the buyback. Those who remained in the industry have been more reliant on sourcing water through the allocation market, which tends to increase risk and variability in profit.

Profitability appears to be dominated by milk prices. For example, 2007-08 was the second most profitable year in the time series, despite having the highest input prices (for both water and feed), because of high milk prices.\(^7\) By contrast, 2009-10 was the least profitable in the time series, despite moderate input prices, because of low milk prices.

To explore the statistical relationships more formally a simple linear regression model was estimated, with milk prices, water prices and feed prices as explanatory variables. Although the sample size was small, the results support the idea that profitability is highly sensitive to milk prices, and that changes in milk prices have been the main driver of recent profitability for the dairy industry in northern Victoria over the period examined.

\(^7\) High water and feed prices were driven, in part, by high milk prices.
Implications for land use and water use

For the other industries examined in these case studies there were relatively fixed relationships between land use, water use and production. This meant that the story was relatively simple – changes in land use and water use are driven by changes in the relative profitability of different activities. The story is more complex for dairy. The relative profitability of dairy farming still influences land use, water use and production. But there can be large changes in water use without changes in the relative profitability of dairy farming.

The production decisions of dairy farmers can be broken down into two related steps. What volume of milk to produce? What mix of inputs (land, water, feed, and so on) to apply to produce that volume of milk at least cost?

In terms of the first question, dairy farming is similar to wine grapes and almonds, in that farmers often have substantial investments in specialised infrastructure. This tends to stabilise production in response to short term variability in producer and input prices (as evident in Figure 21), and delay the adjustment to negative long term trends in producer and input prices. (Asset fixity is discussed in further detail above in Section 5.1.)

In terms of the second question, there are many options for producing milk. Most dairy farmers in the sMDB use a combination of land, irrigation water and purchased feed. It is generally possible to reduce any one of these inputs while maintaining production, provided there is a sufficient increase in the other inputs. For example, production was maintained in 2008-09 by increasing purchased feed to compensate for decreasing the volume of irrigation water applied. In the short run, changes in the input mix are driven by changes in the relative prices of inputs, such as relatively high water allocation prices in 2008-09. This is borne out in the data, which shows a very high positive correlation between the ratio of water price to feed price and the percentage of energy requirements of milking cows purchased (Figure 25). In the long run, changes in the input mix are also influenced by changes in production technology and management practices. For example, investments in irrigation technologies (mentioned above) have changed the least cost mix of inputs. The direction of the impact on water use (for a given level of milk production) is ambiguous and needs to be evaluated on a case by case basis considering the effect of the technology on incentives.
Stakeholders argued that there was likely to be some further contraction of land use and water use in the dairy industry in the sMDB, if water allocation prices increase. Some believed that milk production could be maintained despite higher water prices by purchasing more feed, whereas others contended that the comparative advantage of the dairy industry in the sMDB is the ability to generate feed on farm and that production could move to other regions.
6. Current water demand by industry

This section explores the annual demand for water allocations by industry. Understanding demand for water allocations is important for two reasons. First, it enables us to estimate the changes in water allocation prices associated with changes in demand and supply. Second, it allows us to estimate the changes in water use resulting from changes in allocation prices. These are key objectives of this project.

While this section does not consider demand for water entitlements directly, current and expected future water allocation prices are one of the primary determinants of water entitlement prices. Moreover, water allocation prices are generally more relevant for determining water use, land use and production.

6.1 Estimating water demand curves

In this section, empirical water demand curves are estimated for each industry based on an analysis of publicly available data and quantitative and qualitative evidence from stakeholder consultations. The mathematical formulation is described in detail in Appendix B. The basic concepts underlying the estimation are as follows:

- As the volume of water used by an industry falls, the value of an additional ML of water increases at an increasing rate, and can be described by a mathematical function.

- It is possible to estimate this mathematical function if two different points on the curve are known (Figure 26).
  - One point is based on water use for 2013-14, the most recent year for which ABS data were available. ABS data were used due to its comprehensiveness, however, as discussed in Section 4, there are some inconsistencies with other data sources. Surface water use was estimated by industry under the assumption that all industries in the same NRM region have the same reliance of surface water.
  - The other point is based on the hypothetical price at which demand for water would have become negligible in 2013-14, defined as 20 per cent of actual water use in that year. This is referred to henceforth as the ‘cut off price’. The cut off price is the most important input to the simulations reported in Section 7. Table 2 and Figure 27 summarise the cut off prices used in this analysis, Aither’s confidence regarding these prices, and the basis for selecting these prices.

- There are limits on the volume of water that can be delivered at peak times within an irrigation season, as well as limits on the area of land that can be moved into irrigated production at short notice. Together these factors potentially constrain the volume of water that can be profitably used by an industry in a given year. The volume limits were included for completeness, but were sufficiently high that they had no impact on any of the simulations reported in Section 7. The volume limits were selected based on historical water use.

The remainder of this section examines water demand by industry and compares the results with existing studies.
Figure 26  Procedure for estimating industry water demand

Table 2  Estimated cut off price by industry, 2013-14

<table>
<thead>
<tr>
<th>Industry</th>
<th>Cut off price ($/ML)</th>
<th>Confidence</th>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits and nuts</td>
<td>3000</td>
<td>Low. Potential range 2 000 to 5 000.</td>
<td>Analysis of land values.</td>
</tr>
<tr>
<td>Other</td>
<td>250</td>
<td>Low. Potential range 150 to 350.</td>
<td>Comparison with other activities.</td>
</tr>
</tbody>
</table>
6.2 Grapes

As discussed above, an estimate of the cut off price is required to estimate the water demand curve. Stakeholders noted based on experiences in the millennium drought that applying negligible water to wine grapes in the sMDB would result in permanent damage, and there is a water allocation price at which it was no longer profitable for growers to apply the water needed to keep their vines alive. However, stakeholders found this difficult to quantify, due in part to variation across growers. In making a judgement regarding this price, Aither drew on two sources of evidence.

The first source of evidence was an analysis of land values. As discussed above, typical values for established vineyards were $12,000 to $20,000 per hectare. The difference between the value of established vineyards and vacant irrigable land, which has a value of around $9,000 per hectare, gives an initial estimate of the value of keeping the grape vines alive. This initial estimate can be improved by considering the cost of removing plantings. This is required if the established vineyards do not survive for the full value of vacant land to be realised. This adds around $2,000 per hectare to the value of keeping the grape vines alive, assuming posts can be sold. Hence, the estimated value of keeping the grape vines alive is between $5,000 and $13,000 per hectare.

For a drought that lasts a single year, around 5 ML per hectare could be required to keep established vineyards alive and viable for future years. Under these assumptions, it would be unprofitable for a typical wine grape grower to pay more than $1,000 to $2,600 per ML for water. This result has a number of important caveats. In particular, the cut off price would be lower if the drought was expected to last multiple years, and higher if deficit irrigation was feasible.

The second source of evidence is based on an analysis of farm survey data by Hughes (2011), who estimated a cut off price of around $1,800 per ML. This is equal to the midpoint of the estimates based on land values, and was used to estimate the annual water demand for grapes in the sMDB in 2013-14 (Figure 28). Note that although the estimated curves applied to the simulations reported in Section 7 are smooth, only a small number of points are illustrated in the figures.
6.3 Fruits and nuts

A similar approach was used to estimate the cut off price for fruits and nuts. For any aggregation of many industries, the last major industry within the group to drop out of the allocation market is likely to determine cut off price for the group. This is likely to be almonds based on current profitability.

Current and expected future almond prices are sufficiently high that growers are prepared to pay extremely high water prices to ensure the survival of the plantings. At land values in excess of $50 000 per hectare for established almond orchards, growers would be prepared to pay over $3 000 per ML for water allocations. Accordingly, a cut off price of $3 000 per ML was used to estimate the annual water demand for fruits and nuts in the sMDB in 2013-14 (Figure 29).
6.4 Rice

Many stakeholders had views, based on experience in water markets and the rice industry, regarding the likely cut off price for rice. Most estimates were between $150 and $180 per ML. These values are consistent with low profitability from rice production based on the gross margin analysis in the previous section (Figure 16). The midpoint of stakeholder estimates, $165 per ML, was used to estimate the annual water demand for rice in the sMDB in 2013-14 (Figure 30).

6.5 Cotton

There was disagreement among stakeholders regarding the cut off price for cotton. Some stakeholders argued that cotton production would be attractive until water allocation prices reach around $200 per ML. Others claimed that it is higher than this. This is supported by the gross margin analysis undertaken in the previous section which indicates net returns of around $1 000 per hectare at this water price (Figure 19). Even allowing for imprecision in these estimates, this is likely to exceed the value of alternative land uses. A higher cut off price is also more consistent with observed growth in plantings in 2015, despite water allocation prices being in excess of $200 per ML. Hence, a cut off price of $250 per ML was used to estimate the annual water demand for cotton in the sMDB in 2013-14 (Figure 31). There will be substantial uncertainty around this value until the sMDB cotton industry is tested with higher water allocation prices.
6.6 Dairy

Stakeholders were also divided regarding dairy, with cut off prices between $150 and $220 per ML. Some of these differences are probably due to the relative complexities around water demand for dairy, and exacerbated by substantial differences between farmers. Some stakeholders argued that investments and management changes that have taken place since the millennium drought have contributed to a higher cut off price – a firming of water demand.

Hughes (2011) estimated cut off prices of $260 and $360 per ML for the dairy industry, depending on the assumptions used. On balance, a price of $250 appears plausible, and was used to estimate the annual water demand for dairy in the sMDB in 2013-14 (Figure 32).
6.7 Other agriculture

As discussed in Section 4, other irrigation includes a number of industries that together comprise about 15 to 20 per cent of water use in the sMDB. In addition to the irrigation industries outlined in Section 4, the definition used in this section also captures water used for stock and cleaning dairies and piggeries.

Given the diverse range of activities covered, and the paucity of evidence available regarding water demand for these industries, an alternative way of estimating the cut off price is required. Comparing output per hectare and water use per hectare, other agriculture was most similar to dairy. As a result the same cut off price, $250 per ML, was used to estimate the annual water demand for other agriculture in the sMDB in 2013-14 (Figure 33).

![Figure 33 Estimated annual water demand for other agriculture in the sMDB, 2013-14](image)

Source: Aither estimates.

6.8 Comparison with the literature

The annual water demand curves illustrated above can be compared with the annual water demand curves estimated in other recent MDB studies. The studies used for this comparison are Bell et al. (2007) and Hone et al. (2010), which use statistical approaches, estimating water demand curves based on large datasets.

Elasticities are commonly used to facilitate comparisons across water demand curves estimated in different studies. The price elasticity of demand gives the percentage change in the volume of water demanded in response to a one per cent increase in the price of water. For example, an elasticity of -2 indicates that the volume of water demand would fall by approximately 2 per cent in response to a 1 per cent increase in price of water.

As expected, fruits and nuts and grapes are the least responsive to changes in prices, followed by dairy and cotton, while rice is the most responsive (Table 3). The elasticities are similar to those estimated using different methodologies by Bell et al. (2007) and Hone et al. (2010). In general, the elasticities

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Appendix B provides detail on the how the elasticities were derived in the current study.
are slightly smaller in the current study, indicating that demand is less elastic. This could be because of differences in methodology, or because demand has become less elastic over time – a claim made by some stakeholders.

The comparison with the literature is a way of validating the estimated annual water demand curves, and provides additional confidence that they are plausible.

Table 3  Comparison of current estimates with the literature, water price elasticity of demand

<table>
<thead>
<tr>
<th></th>
<th>Cut off ($/ML)</th>
<th>Aither (elasticity)</th>
<th>Bell et al. (2007) (elasticity)</th>
<th>Hone et al. (2010) (elasticity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grapes</td>
<td>1,800</td>
<td>-0.5</td>
<td>-1.0</td>
<td>-0.3</td>
</tr>
<tr>
<td>Fruits and nuts</td>
<td>3,000</td>
<td>-0.4</td>
<td>-0.8</td>
<td>-0.3</td>
</tr>
<tr>
<td>Rice</td>
<td>165</td>
<td>-1.9</td>
<td>-1.4</td>
<td>NA</td>
</tr>
<tr>
<td>Cotton</td>
<td>250</td>
<td>-1.3</td>
<td>-1.4</td>
<td>NA</td>
</tr>
<tr>
<td>Dairy</td>
<td>250</td>
<td>-1.3</td>
<td>-1.4</td>
<td>-2.0</td>
</tr>
</tbody>
</table>

a Estimates do not distinguish between irrigated broadacre activities.
Source: Bell et al. (2007) and Hone et al. (2010).
Note: Other agriculture not included.
7 Implications of changes in water demand

This section takes the industry water demand curves estimated in the previous section and uses them to explore the implications of future trends in irrigated agriculture that were developed with stakeholders. The section considers the implications for water markets as well as industries that depend on those markets.

7.1 Market demand

The market demand curve is given by aggregating the industry demand curves discussed in the previous section (Figure 34). As environmental managers are now major users of water allocations, environmental demand is also considered in the sense that while estimating the implications of future trends in environmental demand are beyond the scope of this assessment, the implications of future trends in irrigated agriculture are considered in the context of current environmental demand. The environmental water demand curve only includes water purchased through buybacks – it excludes all other environmental water. It is assumed that environmental managers do not trade in the water allocation market, which implies that the environmental water demand curve for 2013-14 is vertical and equal to environmental water allocations in that year. The environmental water demand curve would shift inwards in years with reduced allocations, and outwards in years with increased allocations.

![Environmental demand curve shifts depending on allocations.](image)

Source: Aither estimates.

**Figure 34** Estimated annual water demand in the sMDB, 2013-14

The analysis also reflects the extent to which environmental water buybacks and infrastructure programs have shaped the current demand for water by irrigated agriculture in the sMDB. For
example, some stakeholders contended that these policies had caused a firming of demand in the dairy industry. This would be captured through a higher cut off price for the dairy industry – $250 per ML with these policies and hypothetically $220 per ML without these policies.

Demand by other users – including urban, manufacturing and mining – is not considered. In general these activities account for a relatively small volume of water use in the sMDB, with the exception of diversions for Canberra and Adelaide. Total diversions by other users in the sMDB were around 250 GL in 2007-08 and 110 GL in 2010-11 (MDBA 2009, 2012; irrigated agriculture database). Some of these diversions are outside the allocation market.

7.2 Market supply

Three hypothetical years were considered based on an analysis of allocations in the sMDB over the last 20 years. Supply was assumed to be around 2 000 GL in the low allocation year, 5 000 GL in the moderate allocation year and 6 500 GL in the high allocation year. These values include allocations to entitlements held by environmental managers.

7.3 Demand scenarios

In reality, the demand curves shift over time due to a multitude of factors, including changes in input prices, output prices, rainfall, management practices and production technology. In this analysis, we implicitly hold the values of these variables constant at 2013-14 levels.

Water demand scenarios were developed for 2015-16 and 2020-21 based on conversations with stakeholders in November and December 2015 regarding their expectations for the future (Table 4 and Figure 35). These scenarios show projected expansions and contractions in water demanded if the water price was held constant at $72 per ML. (In the subsequent analysis, water prices are allowed to adjust. The water allocation price is held constant in defining the scenarios to isolate shifts in the demand curve from movements along the demand curve.)

The volume of water demanded at $72 per ML is assumed to be stable for dairy, rice, and other agriculture. The volume of water demanded at $72 per ML is assumed to increase by around 275 000 ML for cotton, 150 000 ML for fruits and nuts, and decrease by 40 000 ML for grapes. This would result in an outward shift in the water demand curves for cotton and fruits and nuts, and an inward shift in the water demand curve for grapes. The market demand curve would also shift outwards.

Based on conversations with stakeholders, the following assumptions are made in developing these projections for the next five years:

- The area of cotton in the sMDB will continue to grow by around 7 000 hectares per year.
- The area of almonds will increase by 15 000 hectares in total, walnuts will increase by 2 600 hectares in total, and hazelnuts will increase by 3 300 hectares in total.9
- Water use by wine grapes will continue to contract by around 2.3 per cent per year.

Sensitivity analysis is undertaken to explore the potential implications of the uncertainty around these assumptions. For example, the potential effects of the recent decline in almond prices are explored as part of the lower projected demand change scenario.

9 Water use by nuts trees tends to increase over the first 10 years after planting, before plateauing. Hence, water use by plantings undertaken in the next 5 years will continue to increase for the next 15 years. Estimated total water use at maturity associated with the plantings projected to be undertaken in the next 5 years is around 270 GL per year.
Table 4  Projected water demanded at $72 per ML in 2015-16 and 2020-21 (ML)

<table>
<thead>
<tr>
<th></th>
<th>Dairy</th>
<th>Rice</th>
<th>Cotton</th>
<th>Fruits and nuts a</th>
<th>Grapes</th>
<th>Other agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-16</td>
<td>1,505,841</td>
<td>825,365</td>
<td>340,030</td>
<td>698,968</td>
<td>375,929</td>
<td>864,267</td>
</tr>
<tr>
<td>2020-21</td>
<td>1,505,841</td>
<td>825,365</td>
<td>615,771</td>
<td>848,459</td>
<td>334,640</td>
<td>864,267</td>
</tr>
<tr>
<td>Change</td>
<td>0</td>
<td>0</td>
<td>275,741</td>
<td>149,491</td>
<td>-41,288</td>
<td>0</td>
</tr>
</tbody>
</table>

a Includes almonds, walnuts and hazelnuts.

Figure 35  Projected water demanded at $72 per ML in 2015-16 and 2020-21

7.4 Will there be sufficient water for all permanent plantings in extremely dry seasons?

Even with the large overall expansions in water demand outlined above for 2020-21, there would be sufficient allocations for all permanent plantings in the sMDB in the event of a repeat of 2007-08. This was the lowest water allocation season in recent history, with just 1,860 GL allocated to entitlements.

The entitlements owned by environmental water managers as a result of buybacks would give the environment around 268 GL of allocations in a repeat of 2007-08, leaving around 1,592 GL for non-environmental users. Total projected demand from permanent plantings is around 1,183 GL (at $72 per ML). Accounting for demand for water allocations by urban, manufacturing and mining users would substantially reduce but probably not eliminate this gap in the short run.

A drawback associated with this type of analysis is that it implicitly assumes that water demand for permanent plantings is homogenous and fixed. In reality, there is some responsiveness to price. This was evident in the millennium drought, with water demand for permanent plantings (especially lower value wine grapes) declining in response to higher water prices. This important subtlety is reflected in the modelling presented below. More generally, even if there is sufficient water for permanent...
plantings in extremely dry seasons, the projected expansions in water demand by cotton and fruits and nuts could have substantial effects on water prices and water use.

7.5 Implications for estimated prices in 2020-21

These projected shifts in water demand will have implications for water prices. Water prices are estimated to increase by 10 per cent in low allocation years and 7 per cent in moderate and high allocation years (Figure 36). These estimates assume no change in environmental demand over time, and that the volume of water carried over from the previous year is equal to the volume carried over to the next year.

The results can be disaggregated to examine the contributions of cotton and nuts to the increase in water prices (Figure 37). The expansion of cotton has similar effects across all years, increasing water prices by around 5 per cent in all years. The expansion of nuts has larger price impacts in low allocation years, increasing water prices by around 6 per cent in low allocation years, 3 per cent in moderate allocation years, and 2 per cent in low allocation years. This is because water demand for nuts is relatively unresponsive to the water price. The contraction in water demand for grapes has a small moderating effect on water prices (not shown).

![Figure 36 Estimated change in water allocation prices in the sMDB between 2015-16 and 2020-21](image-url)

Source: Aither estimates.
Figure 37 Estimated change in water allocation prices in the sMDB between 2015-16 and 2020-21 attributable to cotton and nuts

The water demand model applied in this assessment is based on an annual time frame. In the long run, the increase in water prices would lead to changes in investment and disinvestment, both in agriculture and along the supply chain that would cause further adjustments to water demand. For example, higher water prices in moderate and high allocation years would increase the likelihood of a contraction in the rice processing industry, which would result in lower rice prices, and lower demand for water. As a consequence of these adjustments, the price impacts are likely to be moderated in the long run.

7.6 Implications for estimated water use in 2020-21

These changes in water prices, along with the shifts in water demand, have significant implications for water use (Figure 38 and Figure 39). There is estimated to be a decline in water use by dairy of between 8 and 11 per cent (depending on allocations). The percentage reduction for the rice industry is larger, being more responsive to changes in water prices, at between 12 to 16 per cent. These reductions are entirely due to higher water prices, induced by greater competition for water from other industries. Water use by cotton is estimated to increase by between 61 and 67 per cent, while water use by fruits and nuts is estimated to increase by between 17 and 18 per cent. These increases would have been larger if not for the increase in water prices. Finally, water use by grapes is estimated to fall by between 14 and 15 per cent. This decline is driven by a contraction in demand and exacerbated by higher water prices.

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10 The reduction for the rice industry is smaller than dairy in absolute terms, as the rice industry uses less water, especially in the low allocations year.
7.7 Gains from reallocation

The reallocation of water by market participants in response to changes in water prices, driven by shifts in water demand, will result in winners and losers. Overall, by transferring water from those who
value it less to those who value it more, the market reallocation of water illustrated in Figure 39 is estimated to increase the aggregate net returns from irrigated agriculture in the sMDB by $7 million per year, with the gains being highest in the low allocations year (Figure 40). Note that the overall gains from water trade are much larger, in the order of $60 million to $220 million per year (NWC 2012). This is because the current assessment is only concerned with a component of water trade – the additional trade necessary to accommodate the modelled water demand scenario. It does not include the water trade that occurs every year between market participants, which is already reflected in the baseline.

![Graph showing gains from water trade in the sMDB](image)

Source: Aither estimates.

**Figure 40 Estimated gains from water trade in the sMDB in response to projected changes in water demand**

### 7.8 Sensitivity analysis

Aither conducted sensitivity analysis to explore the quantitative implications of the uncertainty around key assumptions. The sensitivity analysis was based on the following additional scenarios:

- **scenario 1**: lower cut off prices, main projected demand changes
- **scenario 2**: upper cut off prices, main projected demand changes
- **scenario 3**: lower projected demand changes, main cut off prices
- **scenario 4**: upper projected demand changes, main cut off prices.

The parameters used for these scenarios are provided in Table 5 and Table 6. The parameters for scenarios 1 and 2 are based on the potential range of cut off prices identified in Table 2. The parameters for scenarios 3 and 4 are given by the projected demand changes detailed in Table 4, minus and plus 50 per cent.

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51 The gains from trade are measured based on the area under the demand curve and do not include transaction costs or positive and negative externalities.
Table 5  Sensitivity analysis around cut off prices ($/ML)

<table>
<thead>
<tr>
<th></th>
<th>Dairy</th>
<th>Rice</th>
<th>Cotton</th>
<th>Fruits and nuts</th>
<th>Grapes</th>
<th>Other agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>150</td>
<td>150</td>
<td>200</td>
<td>2,000</td>
<td>1,000</td>
<td>150</td>
</tr>
<tr>
<td>Main</td>
<td>250</td>
<td>165</td>
<td>250</td>
<td>3,000</td>
<td>1,800</td>
<td>250</td>
</tr>
<tr>
<td>Upper</td>
<td>350</td>
<td>180</td>
<td>300</td>
<td>5,000</td>
<td>3,000</td>
<td>350</td>
</tr>
</tbody>
</table>

Table 6  Sensitivity analysis around projected demand changes (ML)

<table>
<thead>
<tr>
<th></th>
<th>Dairy</th>
<th>Rice</th>
<th>Cotton</th>
<th>Fruits and nuts</th>
<th>Grapes</th>
<th>Other agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>0</td>
<td>0</td>
<td>137,871</td>
<td>74,745</td>
<td>-20,644</td>
<td>0</td>
</tr>
<tr>
<td>Main</td>
<td>0</td>
<td>0</td>
<td>275,741</td>
<td>149,491</td>
<td>-41,288</td>
<td>0</td>
</tr>
<tr>
<td>Upper</td>
<td>0</td>
<td>0</td>
<td>413,612</td>
<td>224,236</td>
<td>-61,933</td>
<td>0</td>
</tr>
</tbody>
</table>

The sensitivity analysis scenarios affect the magnitude of the impacts, but tend to have little influence on other aspects of the story (see Appendix B for all sensitivity analysis results). The higher the cut off prices, the larger the price effects. However, the change in water use is similar. This is because with higher cut off prices, the volume of water demanded is less responsive to higher water prices. In turn, this explains why water prices have to increase more to clear the water market when demand increases. As expected, the larger the projected changes in water demand, the larger the impacts, both in terms of price and water use.
8. Discussion

Industries are expanding and contracting in response to market forces

There are a number of industries in the sMDB that are highly profitable, such as nuts and cotton, while other industries are considerably less profitable, such as wine grapes. While important, only some of these differences in profitability are driven by water markets. For example, almond trees actually use substantially more water per hectare than wine grapes, but are generally more profitable because almond prices are currently high and wine grape prices are currently low, at least for most varieties. This is not to suggest that water markets have no effects on profitability, especially in industries such as rice where water constitutes a relatively high share of total costs. Yet there is a risk of concentrating excessively on water markets as a driver of profitability in irrigated agriculture, neglecting other important issues.

As a result of changes in profitability, the nuts and cotton industries are expanding rapidly in the southern Murray-Darling Basin (sMDB). Over the next five years, the area of almonds could grow by around 15 000 hectares, with most growth coming in the Riverland, Sunraysia and Riverina. There is also likely to be growth in the area of walnuts and hazelnuts, albeit at a smaller scale. The area of cotton could grow by around 35 000 hectares over the same period. Most of this production is likely to occur in the Riverina. Projected growth in nuts is primarily motivated by high commodity prices, whereas the expansion in cotton is driven by improved varieties and management practices, which increases the relative profitability of cotton relative to alternatives such as rice.

The wine grape industry has been contracting gradually over the last ten years in the sMDB, with irrigated land use falling by almost 3 per cent per year. The majority of this reduction has occurred in public irrigation districts in the Riverland, Sunraysia and Riverina. The changes in the wine grape industry are a delayed and gradual response to low profitability, largely caused by poor prices for many wine grape varieties. It is likely that these trends will continue unless commodity prices improve.

These changes in land use are estimated to increase water demand over the next five years by about 275 GL per year for cotton and 150 GL per year for nuts. Water demand for grapes is estimated to decline by about 40 GL per year.12

Background of increasing water scarcity

In the background are a number of fundamental changes in the water market driving higher water prices. The sMDB appears to be entering another dry spell after a series of years with good rainfall. In addition, a substantial volume of water has been reallocated to the environment (around 1 000 GL of entitlements). An inevitable consequence of this reduction in seasonal water availability and reallocation is that water prices will increase, although reporting the magnitude of this effect is beyond the scope of this assessment (see Aither 2016).

There is also some evidence of a firming of water demand, with irrigators becoming less responsive to increases in water prices. To some extent, this may be a consequence of recent investments in on farm irrigation infrastructure, as well as the shakeout of less profitable irrigation enterprises during the millennium drought. This would result in higher water allocation prices in low water availability years, and is an area for further research.

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12 These shifts in demand are calculated at a water price of $72 per ML.
Potential for substantial changes in water markets and irrigated agriculture

Set against this backdrop of increasing water scarcity, there is the potential for substantial changes in water markets and irrigated agriculture in the event that the projected shifts in water demand outlined above were to eventuate by 2020-21.

Accounting for the reallocation of water to the environment, there would still probably be sufficient water to supply all permanent plantings in a repeat of the worst year of the millennium drought. However, the gap between supply available to permanent plantings in such a year and potential demand by permanent plantings is rapidly closing, and this could be an important issue in the sMDB beyond 2020-21. There would be value in governments undertaking more detailed empirical work on this issue, and communicating the results to the irrigators in the sMDB.

Based on modelling conducted for this assessment, the projected shifts in water demand are estimated to increase water prices by around 10 per cent in low allocation years and 7 per cent in moderate and high allocation years. The bulk of the price increase in low allocation years is due to the expansion of nuts, whereas the expansion of cotton has a larger effect in other years.

These are short run estimated price effects. There is greater capacity to adjust to higher water prices in the long run through investment and disinvestment, and these adjustments will tend to moderate the price effects of the projected shifts in water demand.

The estimated increases in water prices, along with projected shifts in water demand, are consistent with substantial changes in water use by 2020-21. Water use is estimated to decrease by between 8 to 16 per cent for dairy, rice and grapes. At the same time, water use is estimated to increase by around 65 per cent for cotton and around 18 per cent for fruits and nuts (overall – fruits are likely to decline while nuts increase).

There are a number of important caveats around these results. There is uncertainty around some of the assumptions used to develop the water demand model and the projected changes in water demand used to shock the model. The quantitative implications of this uncertainty were explored through sensitivity analysis. The results indicate that the magnitudes of the impacts are sensitive to the assumptions made. Another qualification is that water markets in the sMDB are represented in the model by a single connected market with a common price. In practice, this assumption is violated in some years including 2015-16.

Water markets will be increasingly important

The future trends identified in this report present opportunities and challenges. Water markets can have a substantial impact on irrigated agriculture by reallocating water in response to profitability – from lower value to higher value uses. Although there are winners and losers associated with the estimated water price impacts of the demand increases, there are overall gains from allowing market participants to trade water in response to the projected shifts in water demand. Realising these gains requires open and efficient water markets, including the removal of regulatory trade barriers that do not have a strong rationale. It also requires effective management in the storage and delivery of water. This will become increasingly important as the demand and supply of water adjusts.

Structural adjustment issues could be important

Stakeholders raised concerns about the adjustment implications of changes in demand (and supply). For example, the trade of water allocations and entitlements from some public irrigation districts in the sMDB has resulted in fixed costs being spread over fewer customers, presenting difficulties for both water authorities and remaining irrigators. The potential for stranded assets is well understood. However, this effect could be worsened by the projected movement of water towards cotton and nuts, especially given that many potential developments are outside public irrigation districts, on greenfield
sites. Quantifying the implications of projected changes in water demand for stranded assets is a potential area for further research.

There are also implications for water recovery in the sMDB through infrastructure upgrades to meet the sustainable diversion limits. In particular, there appears to be a risk that a proportion of the infrastructure upgraded could be subsequently underutilised or abandoned as water is traded away. Governments should remain cognisant of possible future trends in water use when providing funding for upgrading water infrastructure. In other words, the challenge is to plan for irrigated agriculture as it will be in 20 years, rather than irrigated agriculture as it is today.

The movement of water into a region can also cause problems. For example, some stakeholders raised concerns about the potential for almond developments below the Choke to increase the risk of delivery congestion.

There are broader structural adjustment issues, some of which are independent of the movement of water. Changes in water use will influence production. The impact on production will depend on the industry. For example, dairy farmers could offset the impact of reduced water use on milk production by purchasing additional feed (although this might not be profitable, especially in the long run). Other industries do not have the same flexibility. Changes in production would also affect people involved in related industries (such as suppliers and processors) and regional communities. For some communities negative trends in one industry could be offset by positive trends in another. To some extent, this is evident with rice and cotton in the Murrumbidgee. Structural adjustment issues should generally be resolved directly (for example, through regional development and welfare policies) rather than through water policies. As a result, the negative impacts of structural adjustment can be moderated while still enabling water to move to its highest value uses.

Further research is required to obtain a better sense of the magnitude of these structural adjustment issues and potential responses. This assessment represents an important starting point.
# Appendix A: Statistical analysis of recent trends

This appendix provides further detail in relation to the statistical trends discussed in Section 4.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Objective</th>
<th>Implementation</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year-to-year variability</td>
<td>To give a sense of the extent to which the variable changes between years.</td>
<td>A regression model was estimated with a linear time trend. The standard error of the estimated regression model gives an indication of the variability around the trend line over time. This was then divided by the mean to facilitate comparisons (across regions and crops).</td>
<td>This procedure is better at distinguishing year-to-year variability from underlying structural trends than simpler descriptive alternatives, such as the coefficient of determination.</td>
</tr>
<tr>
<td>Annual growth (%)</td>
<td>To give a sense of observed trends the variable over the years considered.</td>
<td>The annual growth rate was calculated based on the estimated regression model. The indicator is the annual growth rate required for the variable to grow from the predicted value in 2005-06 to the predicted value in 2013-14.</td>
<td>This is a more accurate reflection of underlying trends in the data over the entire period than the annual growth rate between the actual number in 2005-06 and the actual number in 2013-14, as the later does not account for values of the variable in the intervening years.</td>
</tr>
<tr>
<td>Annual growth, adjusted (%)</td>
<td>To give a sense of trends in the variable over the years considered, adjusting for changes in seasonal conditions.</td>
<td>The regression was run again with total water use as an additional explanatory variable. The annual growth rate was then recalculated, with total water use being held constant it its mean.</td>
<td>The annual growth rate is potentially influenced by seasonal conditions, with water availability improving towards the end of the period considered. Including total water use as an additional explanatory variable reduces the potential for this to bias the estimated trends.</td>
</tr>
</tbody>
</table>
### Table 7  Analysis of the number of agricultural businesses irrigating by region in the sMDB – 2005-06 to 2013-14

<table>
<thead>
<tr>
<th>Region</th>
<th>Murray</th>
<th>Murrumbidgee</th>
<th>Goulburn Broken</th>
<th>Mallee</th>
<th>North Central</th>
<th>North East</th>
<th>Wimmera</th>
<th>SA MDB</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (no.)</td>
<td>1,158</td>
<td>1,697</td>
<td>2,574</td>
<td>1,304</td>
<td>1,924</td>
<td>540</td>
<td>174</td>
<td>2,049</td>
<td>11,420</td>
</tr>
<tr>
<td>Year-to-year variability</td>
<td>0.27</td>
<td>0.06</td>
<td>0.06</td>
<td>0.08</td>
<td>0.09</td>
<td>0.11</td>
<td>0.48</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Annual growth (%)</td>
<td>-1.39</td>
<td>-2.92</td>
<td>-3.78</td>
<td>-4.81</td>
<td>-2.15</td>
<td>-6.05</td>
<td>1.77</td>
<td>-4.66</td>
<td>-3.44</td>
</tr>
</tbody>
</table>

Source: Irrigated agriculture database, based on ABS and ABARES data.

### Table 8  Analysis of land used for irrigation by activity in the sMDB – 2005-06 to 2013-14

<table>
<thead>
<tr>
<th>Activity</th>
<th>Dairy</th>
<th>Rice</th>
<th>Cotton</th>
<th>Fruits and nuts</th>
<th>Grapes</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (ha)</td>
<td>417,980</td>
<td>56,009</td>
<td>10,573</td>
<td>62,894</td>
<td>78,922</td>
<td>197,459</td>
<td>823,838</td>
</tr>
<tr>
<td>Year-to-year variability</td>
<td>0.38</td>
<td>0.78</td>
<td>0.60</td>
<td>0.07</td>
<td>0.15</td>
<td>0.28</td>
<td>0.31</td>
</tr>
<tr>
<td>Annual growth (%)</td>
<td>1.32</td>
<td>17.54</td>
<td>NA a</td>
<td>2.90</td>
<td>-2.73</td>
<td>3.56</td>
<td>2.81</td>
</tr>
<tr>
<td>Annual growth, adjusted (%)</td>
<td>-2.63</td>
<td>6.42</td>
<td>NA a</td>
<td>2.70</td>
<td>-3.14</td>
<td>0.64</td>
<td>-0.56</td>
</tr>
</tbody>
</table>

a Positive growth, but unable to calculate given negative predicted value for 2005-06.
Source: Irrigated agriculture database, based on ABS and ABARES data.
### Table 9 Analysis of water use per hectare by activity in the sMDB – 2005-06 to 2013-14

<table>
<thead>
<tr>
<th></th>
<th>Rice</th>
<th>Cotton</th>
<th>Fruits and nuts</th>
<th>Grapes</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12.4</td>
<td>8.3</td>
<td>6.5</td>
<td>4.6</td>
<td>2.9</td>
<td>3.9</td>
</tr>
<tr>
<td>Year-to-year variability</td>
<td>0.10</td>
<td>0.22</td>
<td>0.20</td>
<td>0.16</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>Annual growth (%)</td>
<td>-0.74</td>
<td>-0.97</td>
<td>6.21</td>
<td>0.60</td>
<td>-0.74</td>
<td>1.91</td>
</tr>
<tr>
<td>Annual growth, adjusted (%)</td>
<td>-0.55</td>
<td>-1.74</td>
<td>4.76</td>
<td>-0.54</td>
<td>-0.51</td>
<td>0.53</td>
</tr>
</tbody>
</table>

#### Notes:
- Positive predicted value for 2005-06.
- ABS and ABARES data.

### Table 10 Analysis of water used for irrigation by activity in the sMDB – 2005-06 to 2013-14

<table>
<thead>
<tr>
<th></th>
<th>Rice</th>
<th>Cotton</th>
<th>Fruits and nuts</th>
<th>Grapes</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,263,170</td>
<td>664,589</td>
<td>411,206</td>
<td>359,992</td>
<td>566,607</td>
<td>3,351,200</td>
</tr>
<tr>
<td>Year-to-year variability</td>
<td>0.53</td>
<td>0.79</td>
<td>0.66</td>
<td>0.20</td>
<td>0.22</td>
<td>0.28</td>
</tr>
<tr>
<td>Annual growth (%)</td>
<td>-0.39</td>
<td>17.19</td>
<td>NA a</td>
<td>9.97</td>
<td>-2.33</td>
<td>3.08</td>
</tr>
<tr>
<td>Annual growth, adjusted (%)</td>
<td>-5.79</td>
<td>5.60</td>
<td>NA b</td>
<td>7.96</td>
<td>-3.86</td>
<td>0.34</td>
</tr>
</tbody>
</table>

#### Notes:
- Positive predicted value for 2005-06.
- NA does not make sense to adjust annual total water use.
- ABS and ABARES data.
Table 11  Analysis of source of irrigation water in the sMDB – 2005-06 to 2013-14

<table>
<thead>
<tr>
<th></th>
<th>Irrigation systems</th>
<th>On-farm dams and rivers</th>
<th>Groundwater</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (ML)</td>
<td>2,306,177</td>
<td>775,927</td>
<td>443,485</td>
<td>50,254</td>
</tr>
<tr>
<td>Year-to-year variability</td>
<td>0.31</td>
<td>0.33</td>
<td>0.19</td>
<td>0.39</td>
</tr>
<tr>
<td>Annual growth (%)</td>
<td>20.93</td>
<td>NA a</td>
<td>-9.80</td>
<td>NA a</td>
</tr>
<tr>
<td>Annual growth, adjusted (%)</td>
<td>-0.56</td>
<td>7.80</td>
<td>-10.26</td>
<td>18.16</td>
</tr>
</tbody>
</table>

a  Positive growth, but unable to calculate given negative predicted value for 2005-06.
Source: Irrigated agriculture database, based on ABS and ABARES data.

Table 12  Analysis of gross value per hectare irrigated by activity in the sMDB – 2005-06 to 2013-14

<table>
<thead>
<tr>
<th></th>
<th>Dairy</th>
<th>Rice</th>
<th>Cotton</th>
<th>Fruits and nuts</th>
<th>Grapes</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ($m, 2013-14 dollars)</td>
<td>3,490</td>
<td>3,989</td>
<td>4,146</td>
<td>18,260</td>
<td>9,171</td>
<td>4,280</td>
<td>5,488</td>
</tr>
<tr>
<td>Year-to-year variability</td>
<td>0.26</td>
<td>0.13</td>
<td>0.10</td>
<td>0.11</td>
<td>0.20</td>
<td>0.33</td>
<td>0.25</td>
</tr>
<tr>
<td>Annual growth (%)</td>
<td>-3.33</td>
<td>-2.58</td>
<td>5.92</td>
<td>-0.54</td>
<td>-0.48</td>
<td>-4.37</td>
<td>-3.06</td>
</tr>
<tr>
<td>Annual growth, adjusted (%)</td>
<td>-1.03</td>
<td>-0.24</td>
<td>5.15</td>
<td>-1.02</td>
<td>0.22</td>
<td>-1.92</td>
<td>-0.83</td>
</tr>
</tbody>
</table>

Source: Irrigated agriculture database, based on ABS and ABARES data.
### Table 13  Analysis of gross value of irrigated agricultural production by activity in the sMDB – 2005-06 to 2013-14

<table>
<thead>
<tr>
<th></th>
<th>Dairy</th>
<th>Rice</th>
<th>Cotton</th>
<th>Fruits and nuts</th>
<th>Grapes</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ($m, 2013-14 dollars)</td>
<td>1,357</td>
<td>161</td>
<td>47</td>
<td>1,037</td>
<td>677</td>
<td>692</td>
<td>3,833</td>
</tr>
<tr>
<td>Year-to-year variability</td>
<td>0.19</td>
<td>0.76</td>
<td>0.62</td>
<td>0.13</td>
<td>0.23</td>
<td>0.13</td>
<td>0.12</td>
</tr>
<tr>
<td>Annual growth (%)</td>
<td>-1.34</td>
<td>13.20</td>
<td>NA</td>
<td>2.40</td>
<td>-2.95</td>
<td>-0.61</td>
<td>0.41</td>
</tr>
<tr>
<td>Annual growth, adjusted (%)</td>
<td>-2.83</td>
<td>3.88</td>
<td>NA</td>
<td>1.68</td>
<td>-2.17</td>
<td>-1.11</td>
<td>-0.56</td>
</tr>
</tbody>
</table>

*Positive growth, but unable to calculate given negative predicted value for 2005-06.*

Source: Irrigated agriculture database, based on ABS and ABARES data.
Appendix B: Figures for sensitivity analysis

This appendix provides figures based on the sensitivity analysis discussed in Section 7.8.

Scenario 1: lower cut off prices, main projected demand changes

![Figure 41](image1.png)  
**Figure 41** Estimated change in water allocation prices in the sMDB between 2015-16 and 2020-21, sensitivity analysis scenario 1

![Figure 42](image2.png)  
**Figure 42** Estimated change in water use in the sMDB between 2015-16 and 2020-21, percentage change, sensitivity analysis scenario 1
Figure 43  Estimated change in water use in the sMDB between 2015-16 and 2020-21, absolute change, sensitivity analysis scenario 1

Scenario 2: upper cut off prices, main projected demand changes

Figure 44  Estimated change in water allocation prices in the sMDB between 2015-16 and 2020-21, sensitivity analysis scenario 2
Figure 45  Estimated change in water use in the sMDB between 2015-16 and 2020-21, percentage change, sensitivity analysis scenario 2

Figure 46  Estimated change in water use in the sMDB between 2015-16 and 2020-21, absolute change, sensitivity analysis scenario 2
Scenario 3: lower projected demand changes, main cut off prices

Figure 47 Estimated change in water allocation prices in the sMDB between 2015-16 and 2020-21, sensitivity analysis scenario 3

Figure 48 Estimated change in water use in the sMDB between 2015-16 and 2020-21, percentage change, sensitivity analysis scenario 3
Figure 49  Estimated change in water use in the sMDB between 2015-16 and 2020-21, absolute change, sensitivity analysis scenario 3

Scenario 4: upper projected demand changes, main cut off prices

Figure 50  Estimated change in water allocation prices in the sMDB between 2015-16 and 2020-21, sensitivity analysis scenario 4
Figure 51  Estimated change in water use in the sMDB between 2015-16 and 2020-21, percentage change, sensitivity analysis scenario 4

Figure 52  Estimated change in water use in the sMDB between 2015-16 and 2020-21, absolute change, sensitivity analysis scenario 4
## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commonwealth water purchases</td>
<td>Commonwealth water purchases refer to water entitlements purchased by the Commonwealth Government under the Restoring the Balance in the Murray-Darling Basin Program, sometimes referred to as ‘buyback’.</td>
</tr>
<tr>
<td>Elasticity</td>
<td>Demand elasticity is the percentage change in quantity of water demanded in response to a 1 per cent increase in price.</td>
</tr>
<tr>
<td>Water allocation</td>
<td>Water allocations are the volumes of water allocated to water entitlement holders during the water year (1 July to 30 June). They are a physical good analogous to a commodity, and are extracted from water courses and applied as inputs to production or the environment.</td>
</tr>
<tr>
<td>Water allocated to all entitlements</td>
<td>Refers to the total volume of water allocated by state governments to water entitlement holders during the water year (1 July to 30 June) – including water entitlements held by environmental water holders. Measured as an aggregate volume at the end of the water year (30 June).</td>
</tr>
<tr>
<td>Water allocated to Commonwealth water purchases</td>
<td>Refers to the total volume of water allocated by state governments to water entitlements held by the Commonwealth associated with the water purchases in the southern Murray-Darling Basin. Measured as an aggregate volume at the end of the water year (30 June).</td>
</tr>
<tr>
<td>Water entitlement</td>
<td>Water entitlements are ongoing rights to receive an annual share of available water resources in a consumptive pool as established in a specific river system, catchment, or aquifer. Entitlements are generally secure, tradeable, divisible and mortgageable in the same way as land.</td>
</tr>
<tr>
<td>Water markets</td>
<td>Water markets are regulated markets where formalised transactions of water entitlements and allocations can occur between parties. There is no single national water market, but rather a number of individual (but in some cases connected) markets. Where hydrological connectivity exists, such as in the sMDB, trade between these markets is possible.</td>
</tr>
<tr>
<td>Water price</td>
<td>Refers to the cleared and contracted transaction price reported of allocation and entitlement trades between parties. It does not account for fees or charges, and is importantly distinct from urban water prices.</td>
</tr>
<tr>
<td>Water year</td>
<td>The water year refers to the period of time between 1 July and 30 June of the following year. It is the same as a standard financial year.</td>
</tr>
</tbody>
</table>
References


Almond Board of Australia 2015. Data provided.


Contemporary trends and drivers of irrigation in the southern Murray-Darling Basin

by Aither

RIRDC Publication No 16/007
RIRDC Project No PRJ-010331