Final Report
Project NS031

# Options for Operating Efficiently and Sustainably within Forest Water Licence Rules

2021

Mount Gambier Centre
Funded by the Australian Government, South Australian Government & Industry Partners.
nifpi.org.au

NATIONAL INSTITUTE FOR FOREST PRODUCTS INNOVATION
MT GAMBIER

# Options for Operating Efficiently and Sustainably within Forest Water Licence Rules

Prepared for

**National Institute for Forest Products Innovation**

**Mount Gambier**

by

**Courtney M. Regan, Jefferey D. Connor, Will Mackay**

**The University of South Australia**

# Publication: Options for Operating Efficiently and Sustainably within Forest Water Licence Rules

**Project No: NIF098-1819 [NS031]**

**IMPORTANT NOTICE**



ISBN: 978-0-9586704-6-3

**Researcher/s:**
Courtney M. Regan, Jefferey D. Connor, Will Mackay.
UNISA BUSINESS
The University of South Australia GPO Box 2471
Adelaide SA 5001

This work is supported by funding provided to Forest and Wood Products Australia (FWPA) to administer the **National Institute for Forest Products Innovation** program by the Australian Government Department of Agriculture, Water and Environment and the Government of South Australia in partnership with the University of South Australia.

Australian Government
Department of Agriculture, Water and the Environment

Government of South Australia
Department of Primary Industries and Regions

# Options for Operating Efficiently and Sustainably within Forest Water License Rules

# Executive summary

## Project background

Since July 1, 2014 all commercial plantation forestry in The Lower Limestone Coast Prescribed Wells Area (LLC PWA) have been required to hold water licenses under the LLC Water Allocation Plan (WAP) and the Natural Resources Management Act 2004.

Under the WAP, the Government of South Australia reserves the right to further reduce water allocations in areas where existing industries are deemed to have a continued high impact on ground water resources. In 2012, a risk assessment was undertaken that identified key Water Management Areas (WMA) where considerable ongoing risk existed to ground water resources from current land uses. Six WMAs namely Coles, Short, Frances, Hynam East, Zone 3A and Zone 5A were identified as being at unacceptable risk of further ground water resource depletion. In these zones, significant further reductions have been proposed to water allocations. While the proposed reductions to allocations have not been finalised, they may be in excess of 50 percent of current allocations, particularly in the WMAs of Coles and Hynam East and in excess of 40 percent in the WMA of Short[1]. This is of concern to the forestry industry as the WMAs of Coles and short contain significant plantation forestry assets (~ 40,000 ha) consisting of both softwood (*P. radiata* ~1,565ha in Short) and hardwood (*E. globulus* ~ 11,200ha in Coles) plantations. Such reductions are likely to have significant impacts on future plantation forestry operations in the Lower Limestone Coast and the revenues of forestry companies operating in South Australia and introduce new complexities for business as usual operations in the region.

## Project objectives

The objective of the project presented here is to enhance the Lower Limestone Coast forest industry's capacity to understand options to effectively and profitably adjust to forest water licensing requirements, specifically:

- Interactive sessions between industry and researchers to develop shared understanding. Validate case study details, water licencing understanding, technical and financial data.

- Develop spreadsheet style financial analysis and case study, explore early results in interactive session to modify in light of industry insights, revise and finalise including assessment of alternate water licence variations.

[1] At the time of writing, reductions had not been finalised. Since this work was carried out a review of the science has been finalised and the reduction in Coles stand as presented here. Reductions in Short will not be occur as stated pending ongoing monitoring.

- Delivery a report for industry to present to the water regulator and for their own consideration

The project evaluated financial and profit implications of alternative strategies to manage forest assets within water licence requirements including options to buy/sell/lease water rights when required or are excess to requirements.

## Scenarios investigated

Several scenarios to assess the various aspects of impact and adaptation were agreed through consultation with industry partners. They differed for the hardwood and softwood industries.

**Hardwood industry scenarios** agreed to represent viable options for a forestry company with hardwood holdings in the WMAs of Coles and Short and include:

1. A business as usual scenario (BAU) assumes no cuts to water allocation and that all land held by the forest companies remain in blue gum production. Rotation length is a choice variable in this scenario and a profit maximisation objective identifies economically optimal rotation length for standing inventory and for subsequent rotations.
2. In the water restriction scenario water allocation reductions become binding when standing timber is harvested. There are 51 percent less allocations than would be required to replant all hardwood areas standing at present. Rotation length as well as locations to replant to maximise profit are the decision variables. It is assumed that land not replanted to hardwoods is converted to non-irrigated pasture and earns the return to this enterprise.
3. A fast or slow conversion to agriculture is also assessed. This scenario is the same as the water restriction scenario outlined above, except that fast or slow conversion to agriculture is possible with faster conversion at higher site renovation cost possible.
4. A sell water scenario includes the option to sell water allocations. No water allocation restriction is considered in this scenario. However, it is possible that by harvesting hardwoods and converting land to dryland agriculture, forest water use is reduced *voluntarily* below held water entitlement reducing demand on ground water resources.

**Softwood industry scenarios** represent viable options for a company with pine holdings in the Short WMA. Short is chosen as opposed to the Coles WMA because of the larger pine inventory and larger proposed cut to water allocations than other WMAs:

1. A business as usual scenario (BAU) assumes no cuts to water allocation and that all land held by the forest companies remains in pine production. Rotation length is a choice variable in this scenario and a profit maximisation objective identifies economically optimal rotation length for standing inventory and for subsequent rotations.
2. In a water restrictions scenario, water allocation reductions becoming binding when standing timber is harvested. There are 44 percent reduction in allocations compared to what would be required to replant all pine areas standing at present. Rotation length and replanting location so as to maximise profit are the decision variables. It is assumed that land not replanted to pines provides no more benefit to the pine industry. Unlike for the hardwood scenarios, conversion to non-irrigated pasture is not possible due to the forest lease conditions. The aim

of this scenario is to understand pine forest sector economic impacts of proposed reductions to water availability.

## Methodology

Representative softwood and hardwood estates consistent with current standing timber in key WMAs of Coles and Short were constructed that describe growth, establishment, maintenance, harvest and transport costs and revenues by site quality. Profit maximisation model was then constructed to calculate the optimal rotation length of the currently established stands and stands replanted after harvest under business as usual and water constrained scenarios.

## Key findings

### Hardwood industry

Two scenarios related to water allocation changes were evaluated. A less optimistic water restriction scenario where water entitlements owned by the hardwood company are assumed to 51 percent of what would be required to replant all currently standing hardwood in the Coles WMA. To remain within these constraints the estate reduces the areas of blue gum plantation replanted in the less productive areas and allocate the land to agriculture with the returns that this earns.

The estimated impact on Net Present Value (NPV) under this scenario is a 13 percent reduction on the modelled BAU case. The NPV of returns to forestry in this scenario decline from $297 million down to $258 million. This includes revenue from land harvested and subsequently leased for agricultural purposes

Under the Natural Resource Management Act, 2004 the Minister may approve an alternative water use reduction scheme for forest water licensees. The sell water scenario provides the company with the option to investigate a voluntary planned reduction in plantation extent in order reduce the current impacts on ground water resources. For example, the sequenced harvesting of hardwood plantations and targeted conversion of some land to agriculture could significantly reduce demands on the ground water resources while maintaining company revenues.

In this scenario we assessed if hardwood companies could harvest timber assets, sell associated water allocation and renovate land for lease to dryland agriculture businesses, under what circumstances this could maintain NPV. To do this we tested a range annual land rental rates ($50, $250 and  $500 per hectare) and water sale prices ($250/ML – $1,500/ML) consistent with permanent water trade prices for the LLC (Waterfind, 2019).

We find that a conversion to agriculture and selling of water entitlements is a profitable option for 20 percent of the area currently planted to hardwood in Coles at a water sale price of $1000/ML and land rental rate of $250/ha/year. The water sale and lease of land for agriculture is optimal for approximately half of all land in Coles in a situation where water prices in excess of $1,500/ML and where land lease rates of $500/ha/year could be achieved. If these conditions could be met, such a course of action would see NPV increase by 7.4 percent to $319 million and reduce water use in the WMA of Coles by 14,769 megalitres.

It is important to note that the option to sell water implies an operational water market has enough scale to absorb the tradable volume. While trading of water does occur, the market for ground water in the region is thin, especially when compared to established irrigation areas in other parts of the country, particularly the Murray-Darling Basin. Data from Waterfind (2019) and WaterConnect (2020) indicates that the size of the water market for permanent water allocations is generally quite low, often below 1000ML of trade per month. Given the size of forest company water holdings the ability to sell such volumes may be optimistic currently. However, some flexibility exists in the LLC WAP to transfer water allocations out of water management zones, to under allocated zones, where it can be used to either support forestry, irrigated agriculture or can be sold. While this scenario was not modelled due to lack of data, this option may provide another viable alternative for forestry companies with significant holding in at risk water management zones.

## Softwood industry

The business as usual scenario calculated profit maximising returns for a continuous pine rotation on a 1565ha estate of diverse site quality blocks established between 2000 and 2016. In this scenario no water allocation constraints restrict replanting after harvest. The estimated NPV of business as usual operations is $20.3 million at a 7 percent discount rate, ($32.3 million at 5 percent). A water restrictions scenario applied a 44 percent reduction in water entitlements to the pine estate relative to the level of entitlement that would be required to replant the entire 1565 hectares of currently standing timber. This reduction in water allocation resulted in -$400,000 (-2%) to -$1.3 million (-4 percent) reduction in NPV from baseline returns at 7 percent and 5 percent discount rates respectively.

In a sense, the finding that a 44 percent reduction in area eventually replanted to pines results in only a 2 to 4 percent reduction in long-run return is surprising. One reason for relatively limited impact is the rather significant discounting of water constraints that only become binding two to three decades into the future. Another primary strategy for reducing water allocation reduction cost identified by the model involves reserving water entitlements primarily for replanting higher productivity sites, and not replanting lower productivity sites.

In response to the industry representative requests we tested the effect on revenue of extending rotation length in order to delay water reductions taking effect. We modelled the options to harvest each standing block at 32, 34, 36, 38, or 40 years after planting and compared this to a scenario that restricted rotation length to only 32 years, consistent with industry practice. The model choses 36 year as the profit maximising rotation length for all standing timber and replanting at a 7 percent discount rate. The result implies that extending rotations by 4 years from 32 to 36 years would have a positive $600,000 (3%) impact on NPV. At a 5 percent discount rate, the optimisation finds that longer 40-year rotations on high and medium quality sites, and 38-year rotations on low quality sites maximise profits and produces higher net benefit.

# Contents

# Tables

# Figures

# Introduction

Since July 1, 2014 all commercial plantation forestry in The Lower Limestone Coast Prescribed Wells Area (LLC PWA) have been required to hold water licenses under the LLC Water Allocation Plan (WAP) and the Natural Resources Management Act 2004. The licenses account for groundwater recharge interception as a result of forestry activities, and for ground water extraction from unconfined aquifers within six metres of the water table. The introduction of the LLC WAP was in response observed changes in water table levels and concerns that continued depletion of this resource would endanger groundwater dependent ecosystems in the region. In 2015, plantation forests were issued with a substantial water allocation for existing forestry plantations of approximately 310,000 megalitres (ML). This allocation endowed many forest owners in the region a new and substantial asset worth an approximated $310 M (if valued at a nominal $1000/ML), with just under half of the forest water licence allocation owned by private forest growers[2]. However, the introduction of the WAP has introduced new complexity and uncertainty into forest operations in the area with changes in the conditions attached to water allocations possible depending on future recovery of ground water resources in the region.

Under the WAP, the Government of South Australia reserves the right to further reduce water allocations in areas where existing industries are deemed to be having a continued high impact on ground water resources. In 2012 a risk assessment was undertaken that identified Water Management Areas (WMA) where considerable ongoing risk existed to ground water resources from current land uses. Six WMAs namely Coles, Short, Frances, Hynam East, Zone 3A and Zone 5A were identified as being at unacceptable risk of further ground water resource depletion. In these zones, significant reductions have been proposed to water allocations. While the proposed reductions to allocations have not been finalised, they may be in excess of 50 percent, particularly in the WMAs of Coles and Hynam East and in excess of 40 percent in the WMA of short. The WMAs of Coles, Short and 3A contain significant plantation forestry assets (~40,000 ha) consisting of both softwood (*P. radiata*) and hardwood (*E. globulus*) plantations. Such reductions, in addition to the complexities posed by the WAP, are likely to have significant impacts on future plantation forestry operations in the Lower Limestone Coast and the revenues of forestry companies operating in South Australia.

Some flexibility exists under the WAP for forest companies to adapt their operations in order to minimise the financial effects of regulation including converting, transferred or selling water. For example, forest water allocation holders can convert forest water licences to water taking licenses and vice versa. Water allocations can also be moved between water management areas, subject to hydrological assessments. In principle, this provides forestry companies the option to allocate water resources to a variety of other water using land uses such as irrigated agriculture, to trade or sell water allocations or covert currently forested areas to dryland agriculture

---

[2] The remainder of forest allocations are owned by the South Australian State Government but made available to OneFortyOne Plantations Ltd under a plantation lease agreement.

enterprises. However, water resource market regulation and management are relatively new to forest managers in the LLC and there are few if any precedents to draw on to understand best management under these new constraints.

The Lower Limestone Coast Prescribed Wells Area (LLC PWA) is believed to be the only water management area in Australia and one of only two in the world (the other being South Africa) where plantation forestry requires a forest water license to operate. In contrast to agricultural irrigators, who have a long history of interaction with water markets and regulation, water market regulation and management is relatively new to forest managers in the LLC and the lack of global precedents to draw on makes understanding best management of water and timber assets challenging.

In May 2018 the Government of South Australia put a hold on any further reductions to allocations in the LLC while a review was conducted into the science underpinning the reductions outlined in the water allocation plan. The forestry industry, through the National Institute for Forestry Products Innovation (NIFPI) has funded two projects in the forest water use space, one looking at the biophysical measurement of forest water use and this project looking at the economic options available for the industry to work within forest water allocation reductions as they are proposed. With that background, the objectives of the research are to enhance the LLC forest industry's capacity to effectively and profitably adjust to forest water licensing requirements and propose any policy changes to forest water licensing requirements that become apparent through the research.  The project evaluated financial and profit implications of alternative strategies to jointly manage forest assets within water licence requirements including options to buy/sell/lease water rights when required.

# Study area

The study area is the Limestone Coast Prescribed Wells Area (LLC PWA) in South Australia, an area covering approximately 1.45 million hectares in the south-east of South Australia (SENRMB, 2019). The region is a one of the State's highest value primary production regions. Agricultural output from the region was valued at approximately $1.25 billion in 2018/2019 (ABS, 2020). The main agricultural crops, by value include broad acre cereal and pulse crops ($177 million), livestock products including wool ($200 million) and dairy ($138 million), potatoes ($100 million) and wine grapes ($75 million)(ABS, 2020). The region also has a significant livestock processing industry ($389 million) and wine production industry (ABS, 2020).

The Limestone Coast also comprises part of the "Green Triangle" (GT) forest region. The GT is one of Australia's major plantation forestry regions and has extensive plantation hardwood and softwood resources, in excess of 200,000 hectares. In 2015–19,  the GT region accounted for 28 percent of the national total availability of plantation hardwood pulp logs and 18 percent of the national total softwood sawlog (ABARES, 2018a). The region also has a significant timber manufacturing industry, primarily processing softwood resources (Schirmer et al., 2008). The

Green Triangle Forest Industries Hub estimates that the region supplies $1.5 billion in forest industry output, comprising 7 percent of total economic output in the GT (GTFIH, 2021).

The LLC contains significant high quality underground water resources in the form of two distinct underground water systems, the upper unconfined Tertiary Limestone Aquifer (known generally as the unconfined aquifer) and the lower Tertiary Confined Sand Aquifer (known generally as the confined aquifer, (SENRMB, 2019)). Declines in confined and unconfined aquifer water levels have been observed in the LLC. These declines have been attributed to a combination of reduced rainfall, underground water extraction and interception of recharge to the aquifer, including by forestry (SENRMB, 2019).

The LLC PWA is divided into 61 Water Management Areas (WMA) in which volumetric allocations are set and water resource condition is monitored. Many WMAs in the LLC PWA are deemed to be at low risk of over allocation. However, several areas including the WMAs of Coles and Short (Figure 1) are seen to be at high risk of over exploitation and are marked for reductions in volumetric allocation. These WMAs currently contain significant forestry assets.

The WMA of Coles (Figure 1) has extensive hardwood inventories with approximately 11,200 hectares in hardwood plantations (ABARES, 2018a). While hardwood is the predominant forestry enterprise, smaller softwood inventories also exist with approximately 566 ha in Coles. This area is currently targeted for significant water allocation reductions of 51 percent (SENRMB, 2013). In addition, much of the hardwood estate in Coles is situated on land where the water table is within 6 meters of the surface (Figure 10). As such, much of the plantation in this area is deemed to be extracting water from the aquifer which results in higher forest water use than plantations where the aquifer is greater than 6 meters in depth (SENRMB, 2019).

The WMA of Short also has extensive hardwood inventories and more substantial softwood inventories than Coles. In addition to approximately 10,057 ha of hardwood plantations, Short also has approximately 1,500 ha of pine plantation (ABARES, 2018b). Like Coles, this area is also targeted for significant forest water allocation reductions of 44 percent. While other WMAs in the LLC PWA have larger softwood inventories, they are not currently targeted for forest water allocation reductions. Short was therefore chosen as a study location as it has significant softwood assets and is also facing substantial allocation reductions. Similarly to Coles, the majority of the forested area in Short is planted above aquifers 6 metres or less in depth (Figure 11).

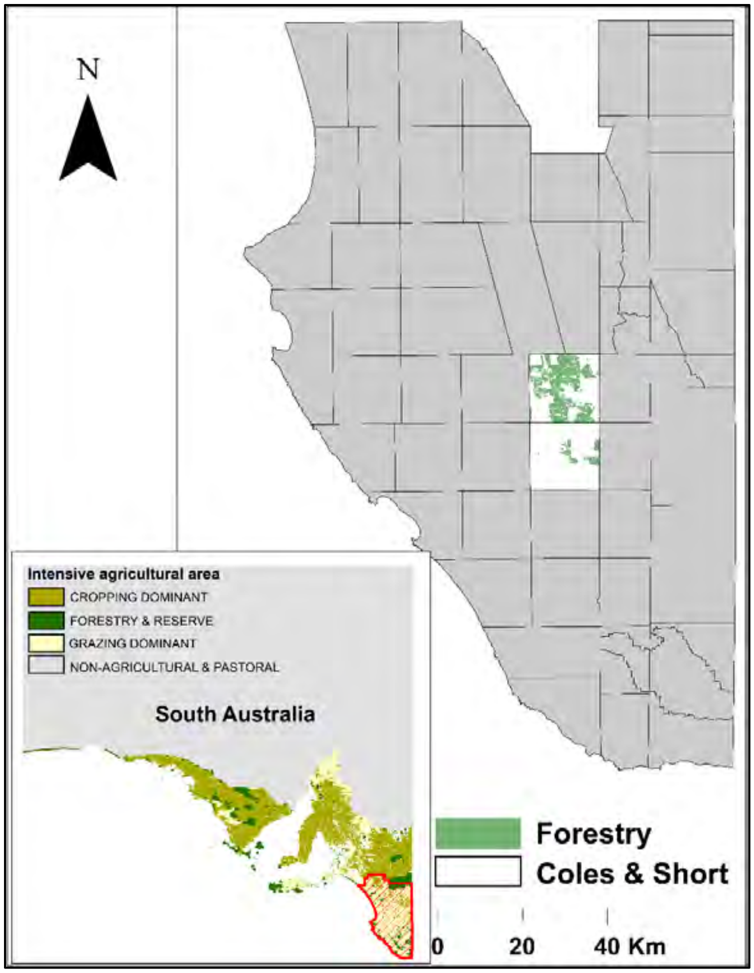



**Figure 1: The Lower Limestone Coast study area. The Coles and Short Water Management Zones and forest inventory.**

# Current forest water use

The LLC WAP provides allocations for commercial forestry attached to a forest water licence which can be used for: (DEW, 2019)

- Existing commercial forests
- Commercial forests clear-felled no more than three years prior to the adoption of the WAP
- Unplanted land where a valid development authorisation exists for a change of land use to commercial forest.

The water allocations account for recharge interception and direct groundwater extraction where a plantation is planted above an aquifer with a depth of six metres or shallower (DEW, 2019). There is a slight difference in assumed water use for softwood and hardwood species, with hardwoods species deemed to have higher ground water extraction rates (Table 1).

Forestry plantations also intercept water (rainfall) that would otherwise recharge ground water aquifers. Again, hardwood and softwood species are deemed to intercept recharge at different rates (Table 1). The amount of water judged to be intercepted by plantations also changes depending on WMA.

**Table 1: Forest water use under the LLC WMP for hardwood and softwood forestry in Coles and Short Water Management Zones**

| | Coles | Short |
|---|---|---|
| **Hardwood ground water extraction rate (ML/ha)** | 1.82 | 1.82 |
| **Softwood ground water extraction rate (ML/ha)** | 1.66 | 1.66 |
| **Recharge rate (mm/ha/year)** | 120 | 150 |
| **Hardwood recharge interception rate (% of total)** | 78% | 78% |
| **Softwood recharge interception rate (% of total)** | 83% | 83% |
| **Forest water use < 6m aquifer (ML/ha) - Hardwood** | 2.76 | 2.99 |
| **Forest water use < 6m aquifer (ML/ha) - Softwood** | 2.66 | 2.91 |
| **Forest water use > 6m aquifer (ML/ha) - Hardwood** | 0.94 | 1.17 |
| **Forest water use > 6m aquifer (ML/ha) - Softwood** | 0.99 | 1.25 |
| **Assumed reductions to forest water allocations** | 51% | 44% |

# Report and project objectives

## Broad level objectives and refinement through stakeholder interaction

At a broad level the project objectives were to:

1. Develop a financial and economic model of LLC forestry
2. Apply the model to
    a. estimate the financial and economic impact that water allocation reduction under the LLC WAP could have on the local forestry industry
    b. assess how a range of adaptations that the industry could make could moderate this impact

Two stakeholder meeting were held to agree more precisely on:

- conceptual representation of forests, implications of water allocation reductions
- parameterisation of forest growth, cost, revenue, water allocations and constraints
- choice of scenarios and adaptation strategies to assess in the economic modelling.

The result was a consensus to:

1. Develop separate pine and blue-gum industry models investigating the economic implication of new water allocation requirements
2. Focus on the WMAs of Coles and Short where there are substantial inventories of standing forest and proposed water allocation reductions are likely to be largest.
3. Agreement on a set of impact and adaptation scenarios to be evaluated.

## Scenarios investigated

Several scenarios to assess the various aspects of impact and adaptation were agreed through consultation with industry partners. They differed for the hardwood and softwood industries.

**Hardwood industry scenarios** agreed to represent viable options for a forestry company with hardwood holdings in the WMAs of Coles include:

1. A business as usual scenario (BAU) assumes no cuts to water allocation and that all land held by the forest companies remain in blue gum production. Rotation length is a choice variable in this scenario and a profit maximisation objective identifies economically optimal rotation length for standing inventory and for current and subsequent rotations.
2. A water restrictions scenario (WR). Water allocation reductions become binding when standing timber is harvested. There are 51 percent less allocations than would be required to replant all hardwood areas standing at present. Rotation length and locations to replant hardwoods to maximise profit are the decision variables. It is assumed that land not replanted to hardwoods is converted to non-irrigated pasture and leased for an annual rent.
3. A fast or slow conversion scenario (FS). The FS scenario is the same as the WR scenario except that fast or slow conversion to agriculture is possible with faster conversion at higher site renovation cost.
4. A sell water scenario (SW). The SW is the same as scenario FS but the additional option to sell water allocation is introduced. This is possible when harvesting hardwoods and converting land to dryland agriculture reduces water use below water allocation.

**Pine industry scenarios** agreed upon represent viable options for a forestry company with pine holdings in the Short WMA. Short was chosen because of the larger pine inventory and large potential additional water constraint. The scenarios include:

1. A business as usual scenario (BAU) assumes no cuts to water allocation and that all land held by the forest companies remains in pine production. The scenario calculates the returns from continued 32-year rotations.

2. The second scenario assesses rotation length as a choice variable and a profit maximisation objective identifies economically optimal rotation length for standing inventory and for subsequent rotations.
3. In a water restriction scenario (WR) water allocation reductions becoming binding when standing timber is harvested. There are 44 percent less allocations than would be required to replant all pine areas standing at present. Rotation length and locations to replant softwood to maximise profit are the decision variables. It is assumed that land not replanted to pines provides no more benefit to the pine industry. Unlike for the hardwood industry, conversion to non-irrigated pasture and earning the return from this enterprise in not possible under the lease conditions that most of the pine industry operates. The aim of this scenario is to understand pine forest sector economic impacts of proposed reductions to water availability.

## Opportunity to develop industry economics capacity

Whilst research reported on here had a very specific objective, this project and second on biosecurity offered the UniSA business school the opportunity to develop industry capacity to evaluate a large range of diverse issues with economic dimensions within the forestry industry. It is hoped that the capacity and relationships being developed through the NIFPI framework will be able to be further developed into the future and employed on other problems with economic dimensions facing the commercial forestry industry.

# Methodology

## Hardwood industry model structure

A hardwood estate representative of current standing timber for the WMA of Coles was constructed that consisted of a range of stand ages planted and mixture of site qualities (see appendix for details). The model firstly calculates the optimal rotation of the currently established stands. This selection is made by maximizing the NPV over the remaining life of current stands and stands replanted after harvest, or not when water restriction precludes some replanting.

In keeping with the proposed changes to available water in Coles as outlined in the LLC WAP, the proposed change to allocation is implemented after the harvest of existing plantations. At which time several options are available to the forestry company. As outlined in Figure 2, the company has the options to; replant all or a portion of the compartment to blue gum, convert all or a proportion of the compartment to a 32-year pine rotation, convert land to pasture through active renovation or slowly via less intensive biological methods.

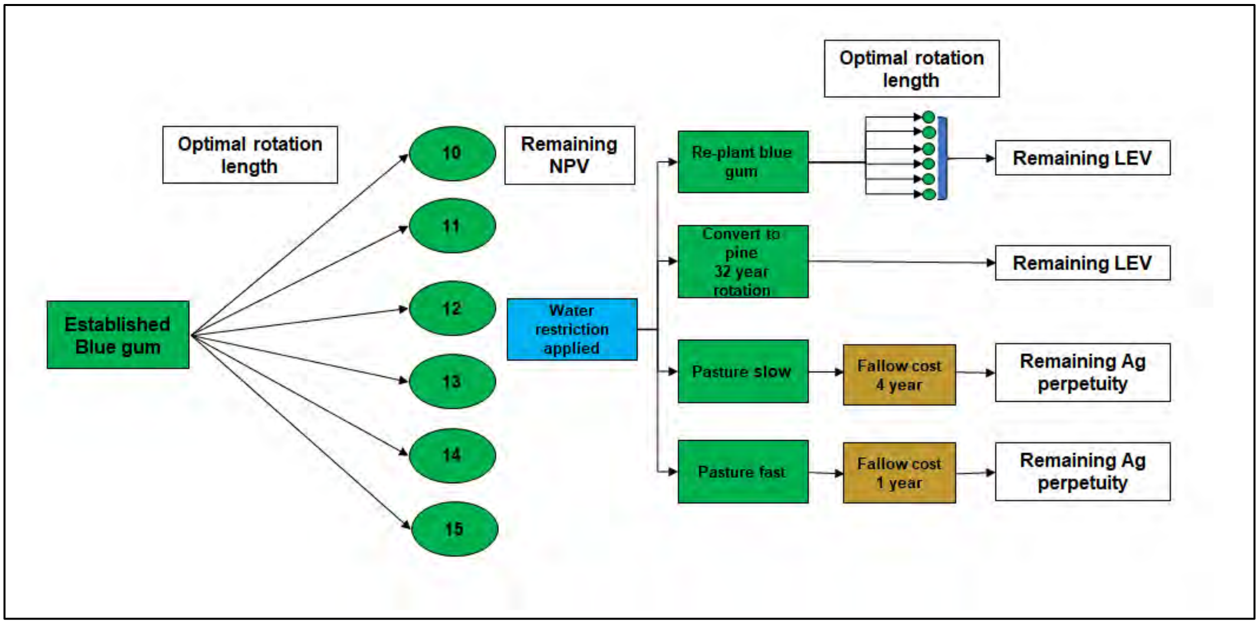



**Figure 2: Schematic representation of the hardwood industry response to water restrictions model**

Figure 3 is a schematic representation of the water sale scenario investigated. Here no binding water restriction applies, however in addition to the options outlined above namely convert to a 32-year pine rotation, fast or slow agriculture conversion or replanting blue gum, the company has the option to sell water allocation for the market water price and convert land to agriculture.

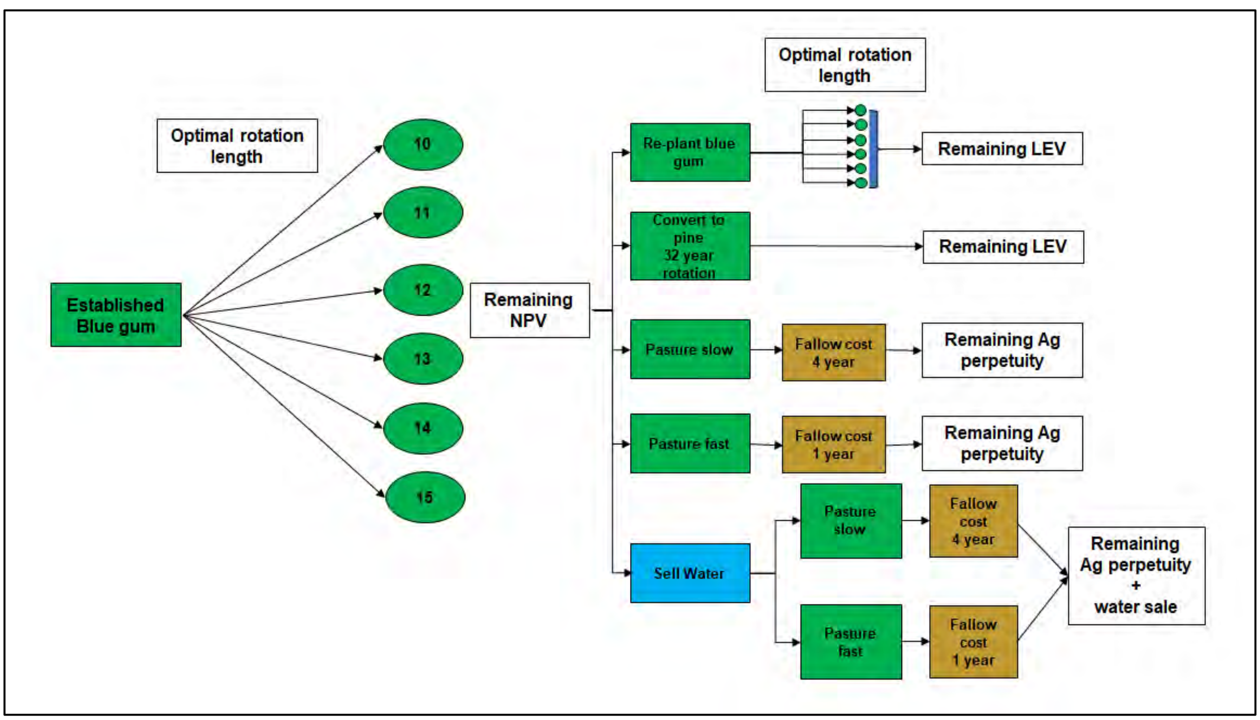



**Figure 3: Schematic representation of the hardwood industry water sale model**

## Pine industry model structure

A pine estate representative of current standing timber for the WMA of Short was constructed that consisted of the actual range of stand ages planted and mixture of site qualities (see appendix for details). The model (Figure 4) firstly calculates the optimal rotation of the currently established stand. This selection is made by maximizing the NPV over the remaining life of current stands and stands replanted after harvest, or not when water restrictions preclude some replanting.

In keeping with the proposed changes to available water in Short as outlined in the LLC WAP, the proposed change to allocations are implemented after the harvesting of existing plantations. At which time the only option available when the water constraint is binding consistent with lease conditions is to not replant all harvest areas back to pine.

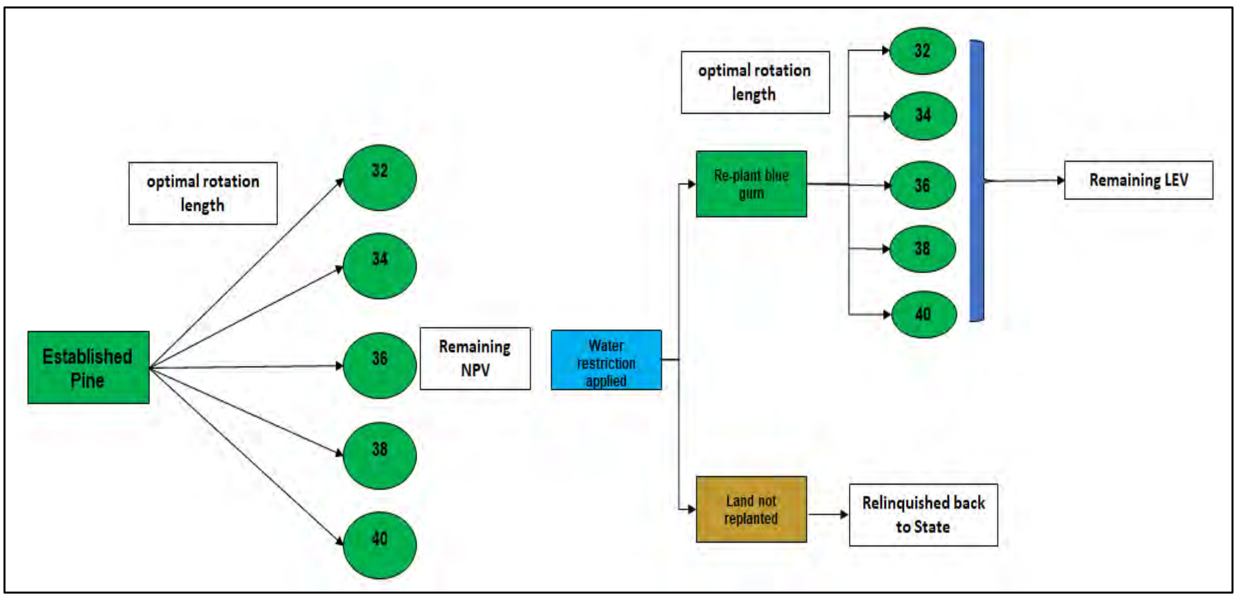



**Figure 4: Schematic representation of the softwood industry response to water restrictions model**

# Results and Discussion

## Impact of water restrictions on the hardwood industry

### Business as usual scenario

The Initial scenario tested was the business as usual case in which no cuts to water allocations are considered. It is assumed all land held by the forest company will remain in blue gum production and provides a baseline revenue for comparison. The decision variable available to the company is rotation length (10-15 years). The results show that the optimal rotation length for most of the estate, at a 7.5 percent discount rate, is 12 years. For the plantations established in 2006 and 2007 the optimal course of action was to harvest those stands at 14 and 13 years of age respectively. For all subsequent rotations the optimal rotation length is 10 years for all site qualities. The net present value (NPV) of managing the estate in this manner is ~ $297 million.

### Water restriction scenario

In the scenario where water restrictions are applied, the company has the option to convert some or all land to an agricultural land use that does not require a water allocation and earn the commensurate return. In this case, the company can lease cleared land to an agricultural company. Under this scenario the optimal course of action is to reduce areas of blue gum plantation in the less productive areas and allocate the land to agriculture (Table 2).

The speed of conversion to agriculture was of interest to the industry partners. As such, two agricultural conversion options were tested in this scenario. The first being a fast conversion back to pasture, which would involve higher up-front reversion costs however, would see the land out of production for only one year. The second decision would be a slower conversion to productive pasture. In this scenario, the up-front renovation costs are significantly lower, however the land is assumed to be out of production for 18 months. In this scenario the optimal course of action for the company is to convert all land to pasture as quickly as possible under the fast-conversion scenario. This result reflects the high opportunity cost of land in the region.

**Table 2: Hardwood area allocations by site quality prior to water restrictions (BAU) and after harvest of standing timber with water restrictions (WR) and a land use change (LUC) option to agriculture (water restriction scenario).**

| | High productivity stands (ha) | Medium productivity stands (ha) | Low productivity stands (ha) | Marginal water price ($/ML) | Total hardwood area (ha) |
|---|---|---|---|---|---|
| **BAU** | 5,600 | 3,360 | 2,240 | | 11,200 |
| **Water restriction scenario** | 4,552 | 1,039 | 138 | 3,656 | 5,729 |
| **Reduction (%)** | 18.7 | 69.0 | 93.8 | | |

The estimated impact on NPV under this scenario is a 13 percent reduction in NPV from the modelled BAU case of $297.1 million to $258.35 million (Figure 5). The marginal value of one megalitre less restrictive water constraint is estimated $3,656/ML. This represents a *shadow price* for water, or the maximum price that management would be willing to pay for an extra unit of the limited resource, water.

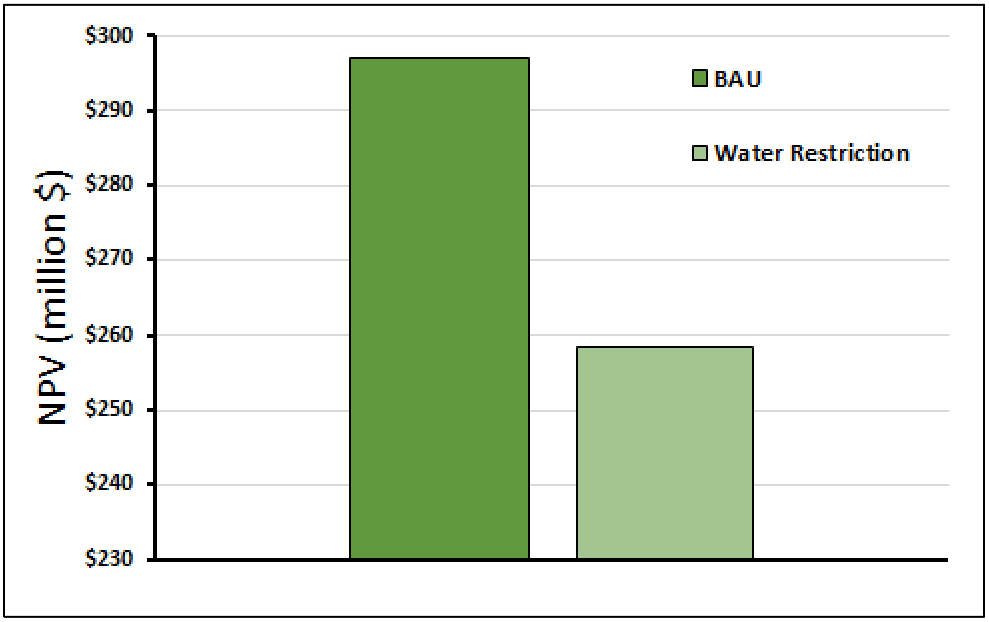



**Figure 5: Comparison of the net present values of business as usual case and scenario 2 where a 51 percent water reduction is applied after harvest of current stands.**

## Water Sell Scenario

Under the Natural Resource Management Act, 2004 the Minister may approve an alternative water use reduction scheme for forest water licensees. The sell water scenario provides the company with the option to investigate the voluntary reduction in forest extent in a manner that minimises economic losses from reduced forestry activities. For example, the sequenced harvesting of hardwood plantations and conversion to agriculture could significantly reduce demands on the ground water resource while maintaining company revenues and may be an acceptable option to manage water use in at risk WMAs.

In a sell water scenario, the company compares NPV of replanting hardwood forestry to the NPV of converting to agricultural land use at the end of each currently standing rotation. In contrast to the water restriction scenario, it was assumed that a company can sell water entitlements when the deemed use from their forest holdings is less than their water entitlement holdings. We tested water prices of $250/ML – $1,500/ML consistent with permanent water trade prices for the LLC which have traded in a range of $600 – $1100/ML in the recent past (Waterfind, 2019).

The results (Table 3) show that at a lower water prices of $250/ML to $500/ML for permanent water trades, no water would be sold, and all land would remain in hardwood production. At prices of $1000/ML and $1,500/ML, the optimal action (for the assumptions outlined above) would be for the company to sell 5,909 ML of water allocation and reduce plantation extent by 2,240 ha. Changing the water price from $1000/ML to $1500/ML did not change the optimal solution, however, as would be expected, the $1500/ML returns a higher NPV (~2 percent) than the $1000/ML water price.

At the higher water prices of $1000/ML to $1500/ML a significant reallocation of land occurred, with 2,240 ha of previously forested area being converted over time to pasture. Water sales at this price would total 5,909 ML. The water sales and conversion to agriculture at a water price of $1,500/ML would see NPV increase to $303.9 million (Table 3).

**Table 3: Net present value and area allocations from a range of water prices in a scenario with the option to sell water allocation to the market and convert land to agriculture at an agricultural lease rate $250/ha.**

| Water price ($/ML) | NPV (million $) | Blue gum (ha) | pasture-fast (ha) | pasture-slow (ha) | water sold (ML) |
|---|---|---|---|---|---|
| **$250** | 297.1 | 11,200 | - | - | - |
| **$500** | 297.1 | 11,200 | | - | |
| **$1,000** | 297.8 | 8,960 | 2,240 | - | 5,909 |
| **$1,500** | 303.9 | 8,960 | 2,240 | - | 5,909 |

Regarding the distribution of forest plantation across the differing site qualities, as would be expected areas lower in productivity are converted to pasture and remaining forest maintained in medium and high productivity areas. At $1500/ML water price only land in the high productivity areas remained in hardwood production.

## Fast or slow conversion to pasture

The results in Table 3 compares revenue from the lease of land at $125/ha (pasture slow) and $250/ha (pasture fast). As outlined in section 0, this reflects a scenario proposed by industry partners as being a realistic representation of current practice. The optimal solution for all the scenarios tested is to outlay higher renovation costs upfront and lease land sooner, as compared to a slower less capital-intensive renovation process. The exact terms of lease agreements (in terms of $/ha) hardwood companies have entered into are not known. In order to test the sensitivity of the results to agricultural lease revenues, we ran several agricultural revenue scenarios incorporating lease rates of $50/ha and $500/ha (Table 4).

The results indicated that agricultural lease rates have an effect on the revenues from the conversion to agriculture option and land allocation. At agricultural land lease rate of $250/ha and below no land use change to agriculture would be expected at water prices of $500/ML or $1000/ML. It is only at a historically high water-price for the region of $1,500/ML that any land conversion and water sale would occur. At $1500/ML and for agricultural lease rates of between

$50/ha and $250/ha the results show that the company would maximise returns if it sold 5,909 ML of permanent allocation and converted 2240ha of previously forested land to agriculture. However, even at a very high water price of $1500/ML, the effect on NPV of the water sales and land use change to agriculture  at $50 and $250/ha/year land lease rate was small ,ranging between 0.5 percent and 1.7 percent increase in NPV compared to the BAU case (scenario 1(Table 4)).  If the optimistic scenario of high water prices and high agricultural lease rate is considered the returns from reducing plantation estate size and selling water allocations would increase the NPV of the company by approximately 7.4 percent.

**Table 4: The effect of agricultural lease revenues on NPV ($ millions) from the option to sell water and reduce forest extent and covert land use to agriculture.**

| | Water price ($/ML) | | | | | |
|---|---|---|---|---|---|---|
| **Agricultural lease rate ($/ha/year)** | **$500** | **% change from BAU** | **$1,000** | **% change from BAU** | **$1,500** | **% change from BAU** |
| **$50** | $297.1 | - | $297.1 | - | $298.6 | +0.50 |
| **$250** | $297.1 | - | $297.8 | 0.23 | $302.1 | +1.68 |
| **$500** | $298.6 | +0.50 | $304.7 | +2.55 | $319.1 | +7.40 |

The options modelled in the *sell water* scenario represents a situation analogous to the current state of the LLC WAP where reductions are a possibility, yet the implementation timeframe is unclear.  The prospect of an as yet uncertain water allocation cut poses considerable risk to forestry companies and if managed poorly could result in revenue decline of upwards of 13 percent (Scenario 2). The results from this scenario show that under the agricultural profitability scenario of $250/ha and a water price of $1000/ML, a feasible course of action for a forestry company would be to reduce the forestry estate and sell water allocations in the medium term and convert land to back to a state fit for agricultural and lease the land.

The results show this course of action would maintain or slightly increase NPV when compared to a business as usual scenario, but would reduce forest extent from 11,200 ha to 8,960 ha (Table 3). It is important to note that the option to sell water implies an operational water market has sufficient scale to absorb the tradable volume. While trading of water does occur, the market for ground water in the region is thin, especially when compared to established irrigation areas in other parts of the country, particularly the Murray-Darling Basin. Data from Waterfind (2019) and WaterConnect (2020) indicates that the size of the water market for permanent water allocations is generally quite low, often below 1000ML of trade per month. Given the size of forest company water holdings the ability to sell such volumes may be optimistic. However, some flexibility exists in the LLC WAP to transfer water allocations out of water management zones, to under allocated zones, where it can be used to either support forestry, irrigated agriculture or can be sold. While this scenario was not modelled due to lack of data, this option may provide another viable alternative for forestry companies with significant holding in at-risk water management zones.

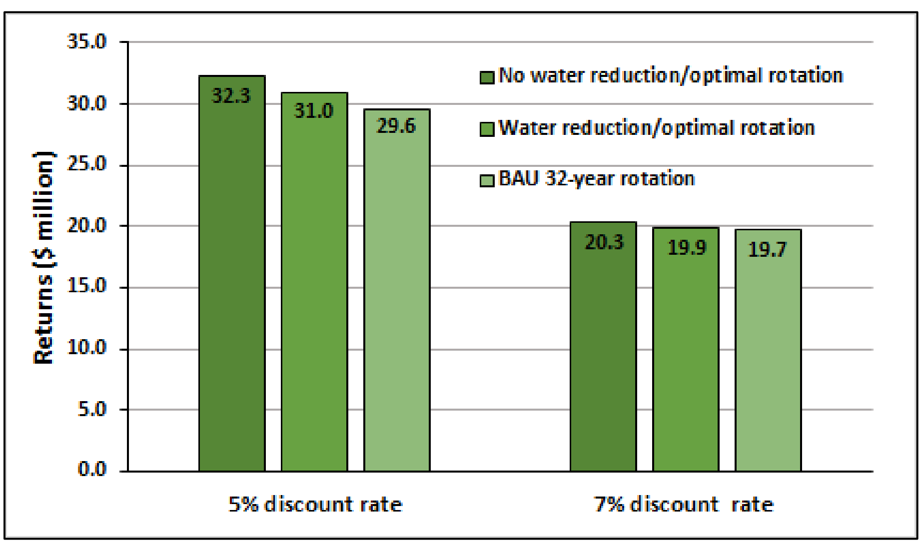
## Pine industry

### Impact of water allocation reduction for Pine Industry

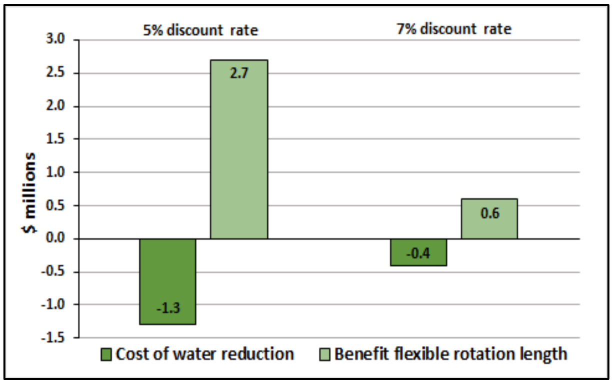
### Business as usual scenario

The business as usual scenario computed profit maximising returns to a continuous pine rotation on a 1565ha estate of diverse site quality compartments established between 2000 and 2016. In this scenario no water allocation reductions restrict replanting after harvest. The estate manager has the options to harvest each standing block at 32, 34, 36, 38, or 40 years after planting. The estimated NPV of this scenario is $20.3 million at a 7 percent real discount rate, and $32.3 million at a 5 percent discount rate (Figure 6A).

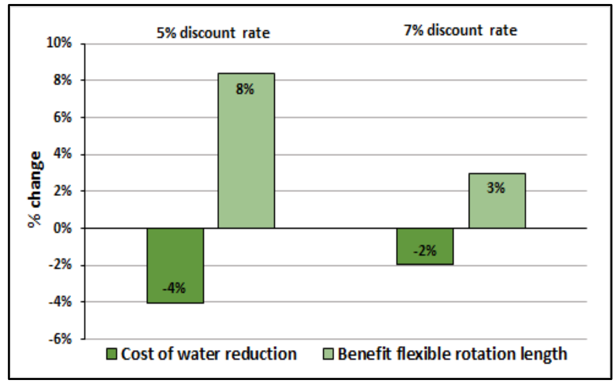
The model choses 36 years as the profit maximising rotation length for all standing timber and replanting at a 7 percent discount rate in comparison to a 32-year rotation, consistent with industry practice. Increasing rotation length from 32 to 36 years increases estimated NPV in the order of $600,000 (3%) (Figure 6B). At a 5 percent discount rate, the optimisation model finds that longer 40-year rotations on high and medium quality sites, and 38-year rotations on low quality sites maximise profits. Naturally, the finding of benefit from extended rotation is dependent on exact parameterisation of the model which should be more carefully interrogated with industry guidance.




A)




B)




C)

**Figure 6: A) returns in perpetuity from 1545 ha representative pine estate in Short WMA with and without water allocation reductions and optimal versus constrained (32-year only) rotation lengths. B) Cost of the water constraint/flexible rotation length ($ millions) compared to no water constraint/flexible rotation scenario and C) Cost of the water constraint/flexible rotation length compared to no water constraint/flexible rotation scenario as a percentage (%).**

## Impact of water allocation reduction for Pine Industry

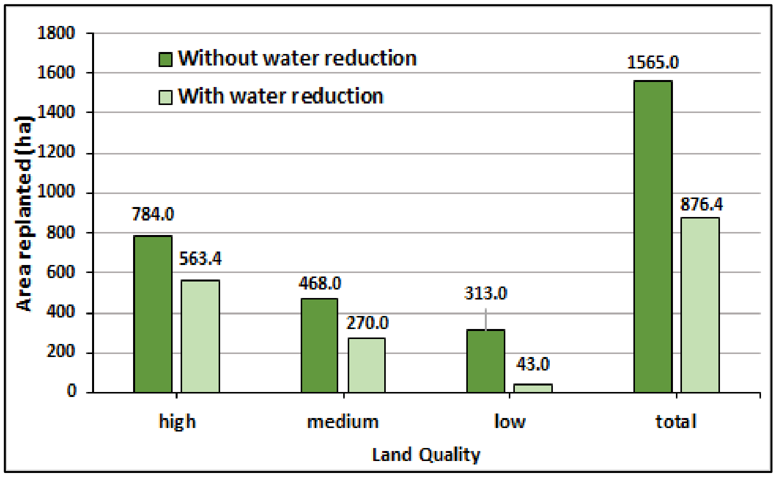
The water restriction scenario represented a 44 percent reduction in water entitlements for the pine estate relative to the level of entitlement that would be required to replant the entire 1565 ha of currently standing timber. The results on replanting were estimated with an optimisation model that chooses sites and years to replant as wells as where and when not to replant, to maximise profit within the constraints of 44 percent allocation reduction.

As indicated in (Figure 7A), only 876 ha of current 1565ha estate is replanted. Two key strategies to reduce adverse economic impacts are revealed in the solution. The first strategy evident in Figure 7A is to focus on replanting higher quality land that have higher returns with 72 percent, 58 percent, and 13 percent of high medium and low land quality sites respectively replanted.

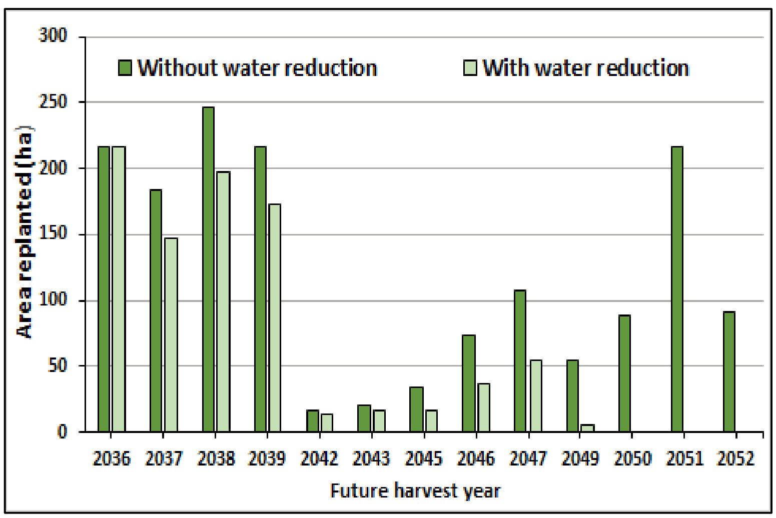
The other main adaptation shown in Figure 7B is prioritisation of replanting of earliest harvested stands. Prior to 2047 most harvested areas are replanted. Beyond that date (and especially beyond 2049) as water constraints become binding, less and less of the area that was once pine stands are replanted. This delaying of reduced replanting reduces costs by considerably discounting distant future forgone pine returns.

The percentage reduction in long-run return over the course of many decades was estimated between 2 percent and 4 percent from BAU at 7 percent and 5 percent discount rates respectively (Table 6). This is much less than in percentage terms than the 44 percent reduction in area ultimately replanted to pine. The difference is primarily a result of the long time horizon until water constraints reduce area that can be planted and the effects of the associated discounting of revenues.

It is also interesting to note that the possibility open to the pine industry to increase rotation length may be able to increase profit by more than water allocation reductions are likely to reduce profit. This can be seen in Figure 6A, where the "BAU 32-year rotation" scenario represents the return to the currently dominant 32-year rotation for the industry. Returns to the "No water reduction/flexible rotation" scenario is $600,000 (3%) higher at 7 percent discount rate as a result of the profit maximising choice to extend rotations by 4 years.




A)




B)

**Figure 7: Area (hectares) replanted to pine A) by site quality and B) area replanted to pine after each future harvest.**

# Conclusion

The Lower Limestone Coast Water Allocation Plan (LLC WAP) was implemented to address the declining condition of ground water resources in the South East of South Australia. As part of the LLC WAP limitations on resource access for ground water using industries have been implemented to ensure long term water resource condition is maintained and to protect ground water dependent ecosystems. Commercial forestry is a significant land use in the area and has been identified as a major user of water resources in the region. The WAP requires that commercial forestry plantations now need to account for their water use by holding forestry water licenses with sufficient allocation to support forestry activities. This is a requirement unique to the forestry industry in Australia and one of only two jurisdictions globally that regulate forest water use. The imposition of these requirements on the commercial forestry industry poses a significant change to business as usual operations for the industry and options for adapting to this new regulatory environment have not been thoroughly explored. The lack of international precedent sees a dearth of information on likely impacts of such regulation to profitability and adaptation strategies for forestry industries in the literature. Further exacerbating the uncertainty caused to forestry operations by the LLC WAP is the prospect that current water allocation levels may be further reduced in Water Management Areas (WMA) deemed to be at high risk of further ground water resource depletion. This is likely to result in additional reductions in plantation extent in those areas.

The aim of this research was firstly to explore the likely economic consequences further water allocation reductions would have on forestry operations in the LLC and; with industry partners develop adaptation strategies and explore their economic basis. Over the course of several workshops with industry partners the divergent requirements of the hardwood and softwood industries became apparent and separate adaptation scenarios were developed for each. The hardwood industry potentially has far greater scope to consider alternative land uses such as conversion to softwood plantations or agricultural land uses that does the softwood industry. The major softwood producer in the region is bound by prescriptive lease arrangements that limit land use to forestry activities only.

Model hardwood and softwood inventories were developed from publicly available data sets and some forest company data and form the basis of the *representative* forest company assets presented here. The analysis centres on the WMAs of Coles (hardwood) and Short (softwood) as these WMAs have both significant forest inventories and are currently targeted for large reductions in water allocations of 51 percent and 44 percent respectively.

The results indicate that for a hardwood plantation manager with assets in the WMA of Coles a 51 percent reduction in water allocation implemented after harvest of standing estates would result in a 13 percent reduction in NPV. This scenario assumes that land not replanted to hardwood would be converted to dryland agricultural production and leased. The results indicate that the optimal course of action for the company would be to convert less productive land to agriculture, concentrating remaining estates on high productivity sites. A question of interest to industry partners was whether the land should be converted back to pasture quickly, thereby incurring larger upfront costs, or slowly thorough less-intensive methods but with reduced or no lease value for a longer period. The results showed that in all cases land should be converted to agriculture quickly, in this instance in one year, and back to full agricultural production as rapidly as possible.

The LLC WAP has some flexibility regarding water transfers and trades and allows for allocations in one WMA to be transferred to another, under allocated WMA subject to hydrological assessment. Additionally, a water market does exist in the region which allows for the sale of temporary and permanent water licenses and their transfer throughout the region. Under the LLC WAP forestry companies can submit an alternative water management plan for consideration by the Minister for Environment and Water. This option may provide companies with the ability to reduce forestry activities in at risk WMAs, such as Coles and Short, by harvesting less productive assets and transferring or selling water assets prior to regulated allocation cuts being implemented or imposed. In order to assess the viability of such an option, we developed a scenario whereby the company could harvest areas, sell water allocations at market rates and convert land to dryland agriculture for lease.

The results of this scenario showed that at water prices of $1000/ML for permanent allocations, the company could maintain or improve profitability by reducing plantation extent. Historical permanent allocation prices have ranged between $500 – $1100/ML. At these prices a company would reduce plantation extent by approximately 20 percent and sell unused water allocations. At a historically high water price of $1500/ML the company would reduce forest extent by 50 percent, which increased NPV by 7.4 percent when compared to a business as usual scenario. A limitation of this scenario is that it assumes an active water market that can absorb this volume of water trade. Current water markets in the region are thin and water trades far below the volumes modelled here. The results are also dependent on the returns from agriculture attainable.

The results assumed the optimal course of action was taken, earning a commensurate lease price of $250/ha/year. The sensitivity of these results to agricultural land lease prices was tested. The results showed that when lower agricultural lease prices were tested the option to sell water was not viable. At agricultural land lease prices of $250/ha and below it was not viable to sell any water allocations and convert land to agriculture at water prices of $500/ML or $1000/ML. Only at the high water allocation price of $1500/ML were modest increases (0.50 – 1.68 percent) to NPV observed when compared to a business as usual scenario. At the high agricultural land lease rate of $500/ha/year, it was found the sale of water and lease of land increased NPV for all water prices tested. Increase ranged from 0.50 percent ($500/ML) to 7.4 percent ($1500/ML).

The softwood industry scenarios were somewhat different in nature to the hardwood industry scenarios. The option to convert land to another land use is not considered in this modelling. Of interest to softwood industry partners was the option to extend rotation length, thereby delaying the implementation of any allocation cuts. Current industry practice is for pine plantations to be harvested after 32 years. We developed a representative softwood inventory in the WMA of Short ranging in age from 4 years to 20 years and planted on land of differing site qualities and productive capacity.

The first scenario calculated returns form a business as usual scenario where all rotations lengths were limited to 32 years and there was no flexibility to change rotation length. By way of comparison the second scenario calculated returns from the plantation estate where rotation lengths were able to vary between 32 years and 40 years. Given the long timeframes involved in softwood forestry the results are sensitive to the discount rate used in the analysis, and we tested the sensitivity of the results accordingly. At a 7 percent discount rate, the results indicate that a softwood plantation manger would optimally extend the rotation length of the estate to 36 years for all standing stock and that subsequent rotations also be extended to 36-year rotation. The results show that extending rotation length to 36 years would increase the NPV from the fixed rotation length scenario by approximately 3 percent. This comparison did not include a water restriction. At a 5 percent discount rate, the optimal rotation length increased further to 40 years on high and medium site qualities and 38 years on low quality sites. The ability to vary rotation length increased the NPV by 8 percent on the business as usual scenario at this discount rate.

The WMA of Short may have forest water allocations cut by up to 44 percent. At a 7 percent discount rate, the results indicate that a cut in allocation of this magnitude would decrease NPV from softwood forestry by 2 percent over the long term and by 4 percent at a 5 percent discount rate. The effect of the water constraint on plantation extent however is significant and would reduce the modelled estate from the current 1545 ha to 876 ha in the long term. As would be expected, in the water constrained scenario, the profit maximising strategy is to shift forestry to high and medium site qualities, with virtually all low-quality sites not replanted to softwood. The small size of the reduction to NPV would appear incompatible with the size of the water allocation reductions, however the size of the effect can be explained by the fact that reductions were modelled to only take place after the harvest of existing stock. As a result, the reductions take place a long time in the future and the resultant discounting of future costs reduces their impact to the small levels reported here.

While the results presented in this report show seemingly viable adaptation options for the forestry industry in response to the LLC WAP, they do not account for the effect on other factors such as the impact reduced timber volumes have on other variables. For example, on contractual delivery arrangements, processing economies of scale or flow through effects to other industries such as transport, forestry services contactors or employment in the region. This was beyond the scope of this study. The results are also contingent on the assumptions made regarding plantation ages, productivity and the costs and returns from forestry and agricultural enterprises. These parameters were largely estimated from publicly available data and approximate figures provided by industry. Changes to these parameters would necessarily change the outcomes of the modelling. As such the results are not directly transferable to anyone company's actual circumstances. More important than any specific result is that the modelling presented here provides a framework with which to conceptualise and address the challenges posed to the commercial forestry industry by the LLC WAP and evaluate a range of adaptation options. However, populated with more tailored data, this modelling framework can be further developed in order to address specific questions regarding the impact of proposed changes to the LLC WAP, the economic effects of further water use restrictions and the viability of adaptation options. Further work could also explore the potential for this framework to be integrated into existing industry optimisation programs or utilised as a baseline to address other economics issues facing the industry.

# Appendix: formal description of model

## Data

### Plantation Forest Extent

Data providing estimates of forest inventory within the study area were sourced from the Australian National Forest Inventory (ANFI) *Forests of Australia 2018* data set (ABARES, 2018b). Forests of Australia 2018 dataset is a continental scale spatial dataset of forest extent arranged by forest categories and type and is assembled from multiple forest, vegetation and land cover data inputs (ABARES, 2018b). The ANFI 2018 estimation of hardwood extent can be seen in Figure 8. Data was extracted from the spatial datasets to provide an estimation of total hectares for the WMA of Coles and Short. The extent of the hardwood estate is summarised in **Error! Reference source not found.**.

Data outlining the age distribution of the hardwood estate in the study area was not available. However, the Australian National Forest Inventory (ABARES, 2018a) provides statistics of areas planted for the past two decades which show hardwood planting peaked in the period 2006-2010 and have declined substantially since that time. We assume for the initial inventory development that the age distribution of plantations in the area follow a similar distribution, with 80 percent of the estate being planted between 2006-2010 and 20 percent between 2011 and 2015 (**Error! Reference source not found.**).

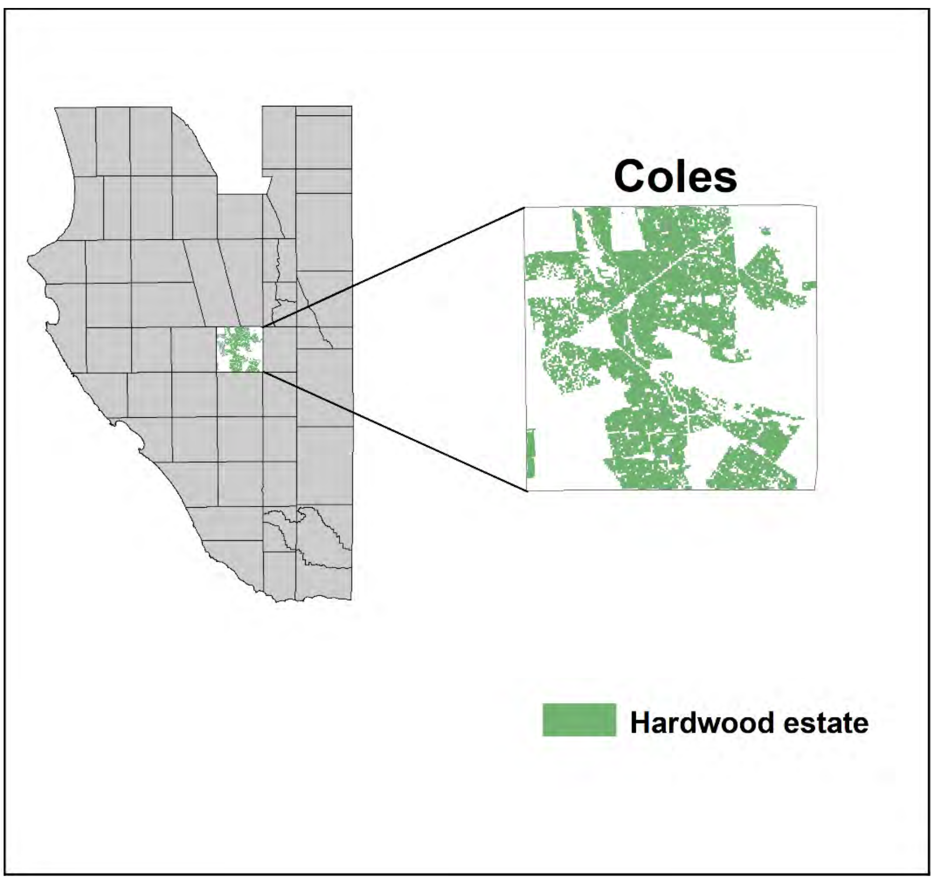


**Figure 8: Hardwood Inventory for the Coles Water Management Zone (ABARES, 2018b).**

**Table 5: Hardwood area data extracted from ABARES (2018b)**

| | Hardwood Area (ha) | Hardwood Area (ha) < 6 metre aquifer | Hardwood Area Planted 2006 -2010 (ha) | Hardwood Area Planted 2011 – 2015 (ha) |
|---|---|---|---|---|
| **Coles** | 11210 | 10473 | 8408 | 2803 |

Data outlining the Softwood inventory for the WMA of Short was provided by one of the industry partners and is commercial in confidence and therefore not published in this report. ABARES (2018b) Australian National Forest Inventory provides a publicly available estimation of softwood plantation extent for the region (Figure 9) and this provides a good approximation for comparison.

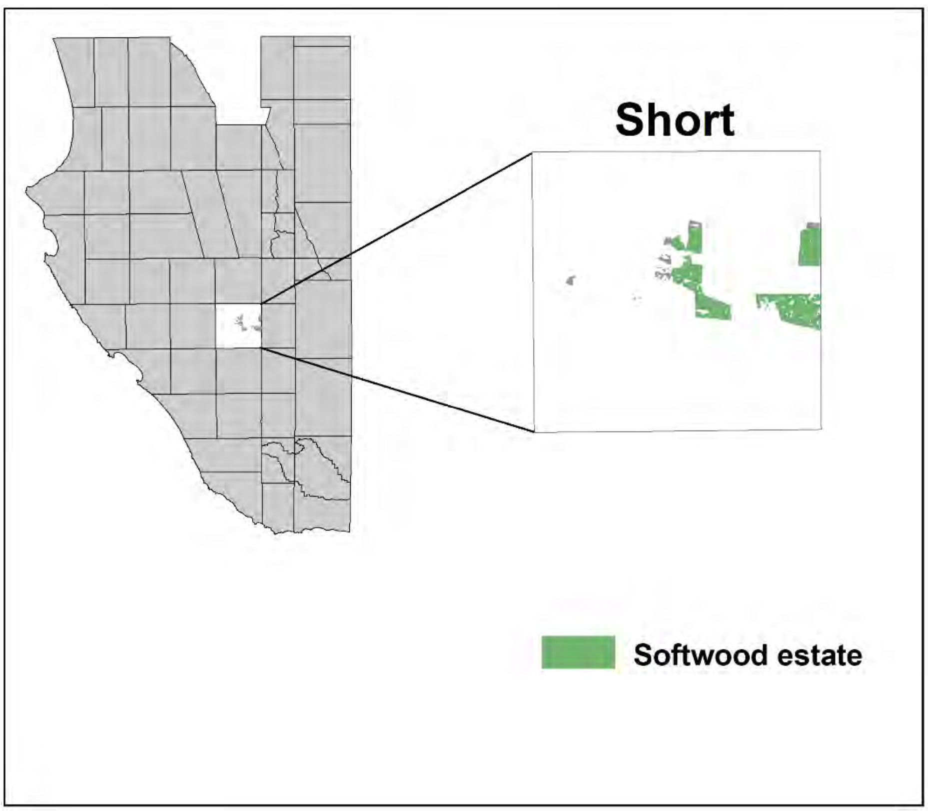



**Figure 9: Softwood Inventory for the Short Water Management Zone (ABARES, 2018b).**

**Table 6: Softwood area data extracted from ABARES (2018b)**

| | Softwood Area (ha) | Softwood Area (ha) < 6 metre aquifer |
|---|---|---|
| **Short** | 1565 | 1565 |

## Depth to ground water

In addition to plantation extent and age distribution, another important factor is the extent of the hardwood plantation estate situated above ground water tables less than 6 metres in depth. In order to calculate this, data from the Department of Environment and Water *groundwater interception likelihood* spatial layer (DEW, 2017) was extracted and combined with ANFI data (ABARES, 2018b). Figure 10 and Figure 11 display the forest extent estimated to be deemed ground water extracting. For softwood plantations in Short, we estimated 100 percent would be deemed to be ground water extracting.

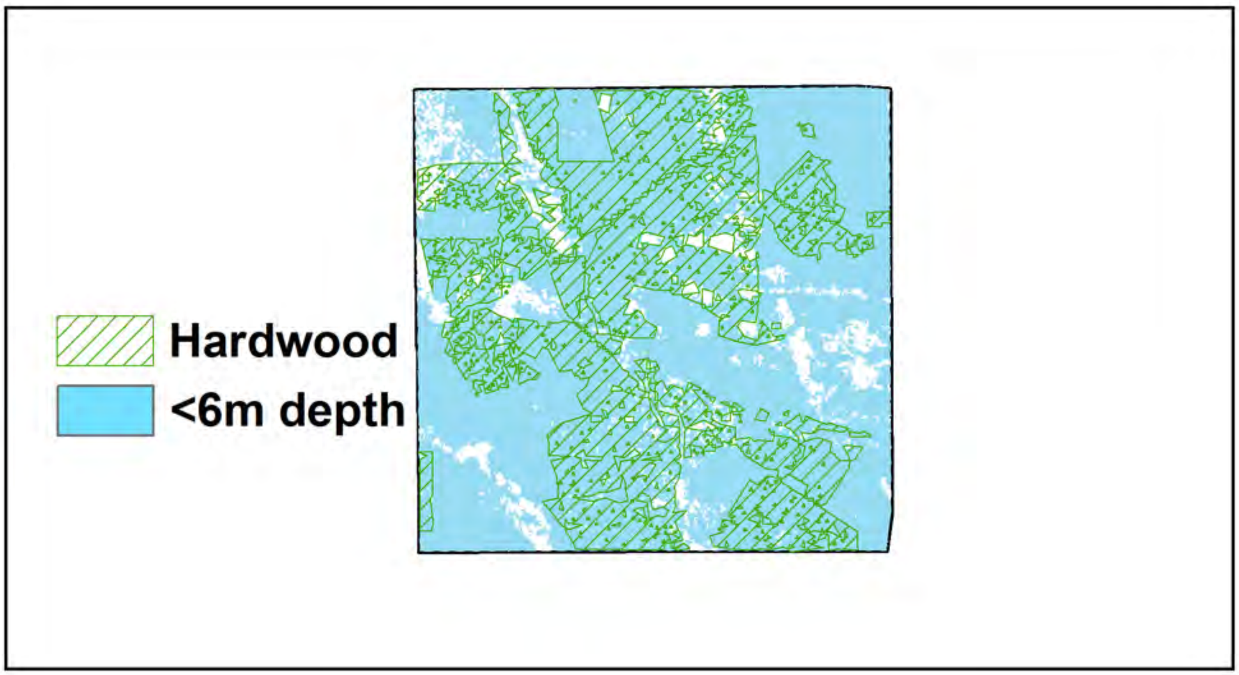



**Figure 10: Forest inventory for the Coles Water Management Zone and area with a depth to ground water of < 6 meters.**

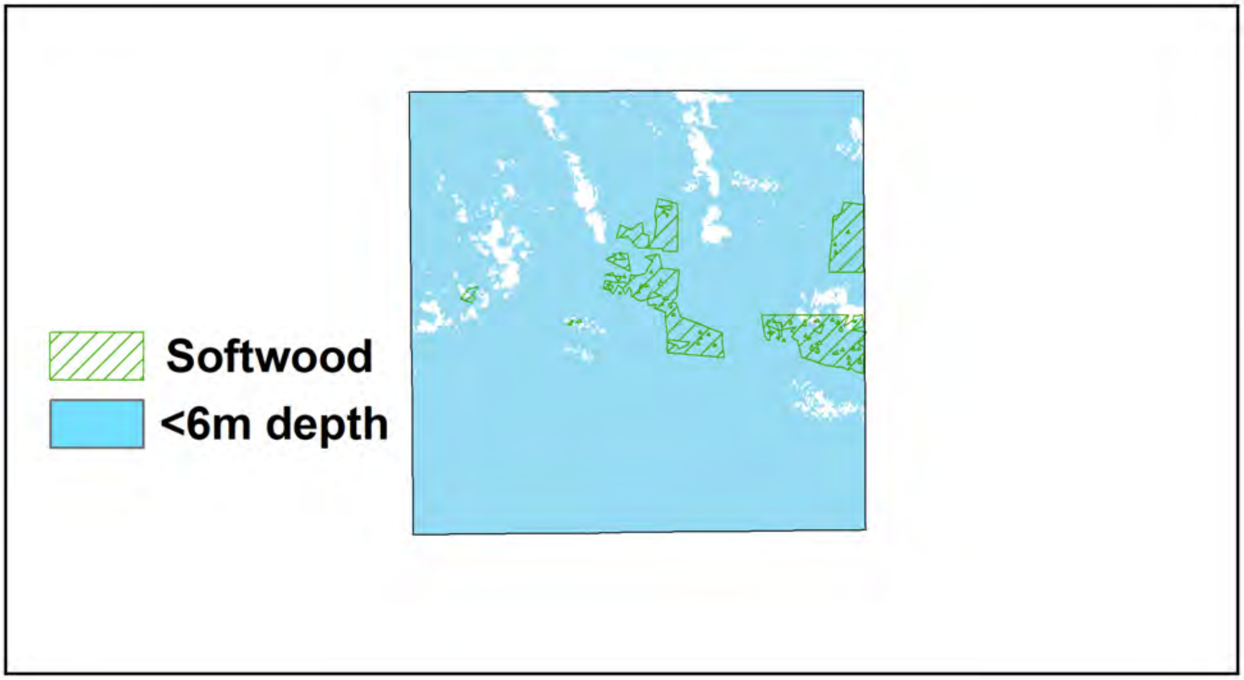



**Figure 11: Forest inventory for the Short Water Management Zone and area with a depth to ground water of < 6 meters.**

## Hardwood yield estimates

To calculate hardwood yields, modelling developed for Forestry SA by Leech (2003) was implemented. The model is based on a general form of the von Bertalanffy equation (Von Bertalanffy, 1949). Leech (2003) provides estimates of volume on a per hectare basis for different assumed site productivity classes (Figure 12). To capture the site quality variability in the LLC, expert opinion was sought on the most appropriate yield curves to use in order to obtain representative growth curves for the study area. The yield curves selected correspond with a 10-year productivity of 150m$^3$, 200m$^3$ and 250m$^3$ and represent high, medium and low productivity sites for the study area.

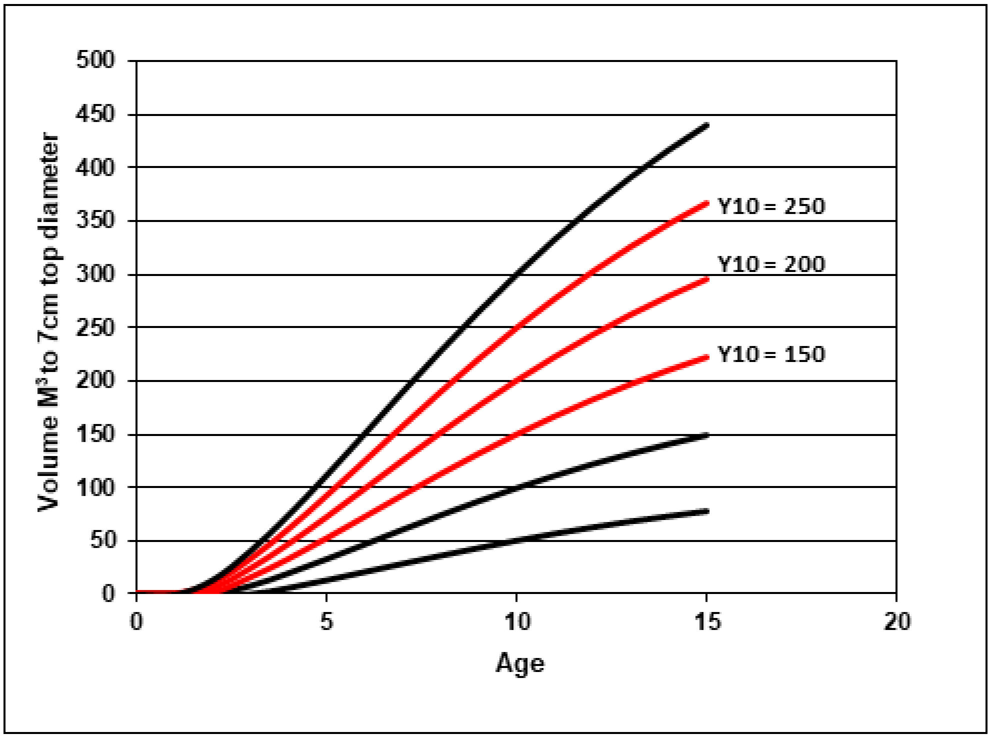



**Figure 12: Hardwood yields modelling taken from Leech (2003). The red highlighted curves were used in this study.**

## Site quality

To implement the forest yield model outlined an estimation of site qualities across Coles and Short was made. No forestry specific region wide data on land suitability for forestry exists so estimates were made using the South Australian Department for Environment and Water *soil and land attribute* data (DEW, 2009). The data identifies 61 different soil types across South Australia and groups them into 15 broad soil groups. Broadly, sandy type soils (i.e. deep sands, sand over clay) we allocated as most productive for forestry and shallow soils on calcrete or limestone were allocated as least productive (Figure 13 and Figure 14).

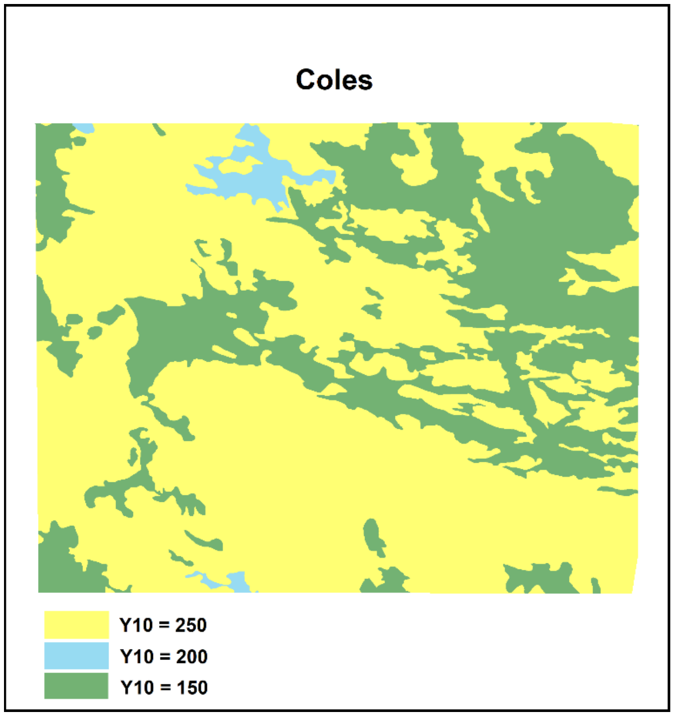



**Figure 13: Estimated site quality in the Coles Water Management Zones derived from DEW (2009) soil and land attribute data.**

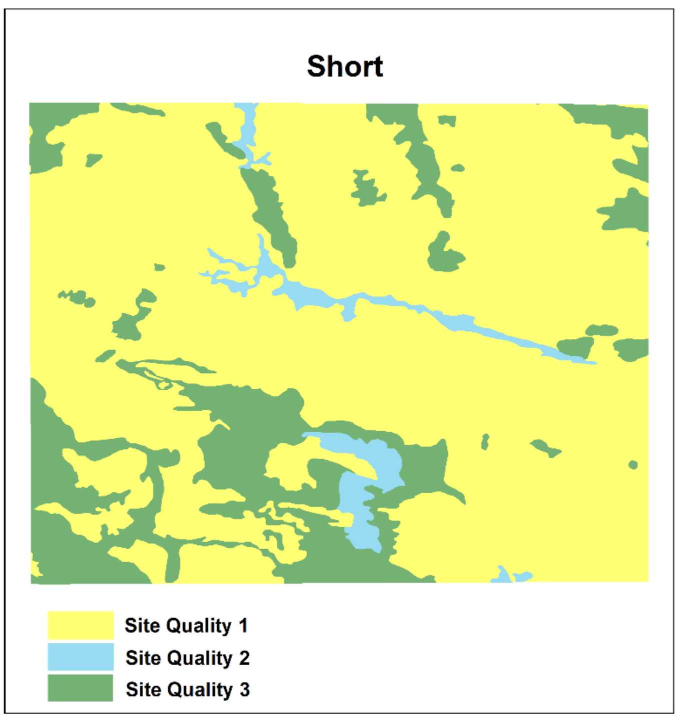



**Figure 14: Estimated site quality in the Short Water Management Zones derived from DEW (2009) soil and land attribute data**.

With this information the representative forest estate used in the model was created. While spatial data has been used in this process, the modelling is not spatially explicit. Forest blocks have been allocated according to planting year and within that, areas allocated to site quality and water use (i.e. depth to aquifer). For example, forest *2006* comprises 1682ha, 1571ha of which are planted on land with a depth to aquifer of less than 6 metres, with 785ha being in site quality $Y10_{250}$, 471ha in site quality $Y10_{200}$ and 314ha being in site quality $Y10_{150}$ and so forth.

**Table 7: Representative hardwood estate inventory for the WMA of Coles, by site quality and depth to aquifer.**

| | | | < 6m to aquifer | | | > 6m to aquifer | | |
|---|---|---|---|---|---|---|---|---|
| **Year Planted** | **Total area (ha)** | **Area < 6 metre to Aquifer (ha)** | **$Y10_{250}$** | **$Y10_{200}$** | **$Y10_{150}$** | **$Y10_{250}$** | **$Y10_{200}$** | **$Y10_{150}$** |
| **2006** | 1682 | 1571 | 785 | 471 | 314 | 55 | 33 | 22 |
| **2007** | 1682 | 1571 | 785 | 471 | 314 | 55 | 33 | 22 |
| **2008** | 1682 | 1571 | 785 | 471 | 314 | 55 | 33 | 22 |
| **2009** | 1682 | 1571 | 785 | 471 | 314 | 55 | 33 | 22 |
| **2010** | 1682 | 1571 | 785 | 471 | 314 | 55 | 33 | 22 |
| **2011** | 561 | 524 | 262 | 157 | 105 | 18 | 11 | 7 |
| **2012** | 561 | 524 | 262 | 157 | 105 | 18 | 11 | 7 |
| **2013** | 561 | 524 | 262 | 157 | 105 | 18 | 11 | 7 |
| **2014** | 561 | 524 | 262 | 157 | 105 | 18 | 11 | 7 |
| **2015** | 561 | 524 | 262 | 157 | 105 | 18 | 11 | 7 |

The data used in the Short softwood model came from actual company inventory and was provided to the research team as commercial in confidence data and as such cannot be published in the report. By way of approximation, data extracted from the Forest of Australia data (ABARES, 2018b) show that softwood inventory in Short is 1545 ha. We assumed stand ages ranging from 20 years to 4 years of age.

## Softwood yields

Data for softwood yields was adapted from Forestry SA yield tables (Lewis et al., 1976). The BAU scenario considers a 32-year pine rotation, the assumed harvest volumes are shown in **Error! Reference source not found.** for three site qualities "high", "medium" and "low" (SQ1 – 3). These site qualities were deemed appropriate after consultation with foresters in the region (O'Hehir, J., Dobson C., pers. Comms 2020).

**Table 8: Estimated harvest volumes for a 32-year pine rotation taken from Forestry SA yield tables.**

| Volume ($M^3$) | | | |
|---|---|---|---|
| | High productivity (SQ1) | Medium productivity (SQ2) | Low productivity (SQ3) |
| Thinning 1 | 151 | 124 | 98 |
| Thinning 2 | 99 | 90 | 110 |
| Thinning 3 | 127 | 109 | 132 |
| Thinning 4 | 103 | 87 | - |
| Clear fall | 660 | 612 | 552 |

The volume at each thinning is divided proportionately between different log classes and sizes, including sawlogs, log plywood, pulpwood, preservation and chipping log according to Forestry SA data.

The same process was followed to obtain yield data for 34-40-year softwood rotation lengths used in the softwood modelling.

# Economic parameters

## Hardwood

The costs associated with the production of blue gum were obtained through industry consultation. Foresters from PF Olson provided estimates of the cost of production (Winkley, N., Dobson C., pers. Comms 2020).

**Table 9: Costs associated with E. globulus production**

| | |
|---|---|
| blue gum chip price ($/t) | 115 |
| | |
| transport cost ($/t/km) | 0.16 |
| Site preparation ($/ha) | 970 |
| Planting costs ($/ha) | 410 |
| Establishment fertiliser ($/ha) | 200 |
| 2nd Year fertiliser ($/ha) | 230 |
| Annual Maintenance ($/ha) | 80 |
| Other Contractor costs ($/ha) | 20 |
| Harvesting costs ($/t) | 15 - 35[3] |
| Assumed planting density (stems/ha) | 1000 |

[3] Cost varies according to harvesting method with estimates of Cut to Length = $15-$20/t and infield chipping = $30-$35/t.

## Conversion to agriculture

The parameters used in this scenario were constructed with input from industry partners. The modelling assumes properties being converted are not managed by the forestry companies but converted to pastureland and leased for an annual rent. The optimal speed of conversion was highlighted as an area of interest in industry consultations. Of interest was a low cost, longer time frame conversion versus higher input fast conversion to pasture. Estimates for reconversion costs and time taken were estimated through industry consultation.

**Table 10: Costs associated with conversion to agricultural enterprise.**

| | |
|---|---|
| **Lease price - fast conversion ($/ha/year)** | 125 |
| **Lease price - slow conversion ($/ha/year)** | 250 |
| **slow reconversion to pasture ($/ha)** | 500 |
| **fast reconversion to pasture ($/ha)** | 2000 |
| **Slow reconversion time (months)** | 18 |
| **Fast reconversion time (months)** | 12 |

## Softwood

As outlined above modelling of softwood rotations was done with Forestry SA yield tables (Lewis et al., 1976). Commodity prices for various log classes were taken from the latest publicly available data, namely the *Australian Pine Log index (stumpage) report* (KPMG, 2018) and through consultation with industry partners.

## Costs and revenues associated with conversion to P. radiata

**Table 11: Assumed log prices used in modelling pine plantation economics.**

| | **Price range ($/m$^3$)** | |
|---|---|---|
| | **Minimum** | **Maximum** |
| **Sawlog** | 41 | 113 |
| **Plywood** | 66 | 100 |
| **REC** | 41 | 44 |
| **Pulplog** | 38 | 38 |
| **preservation log** | 32 | 70 |
| **Chiplog** | 28 | 28 |

The costs of production were taken from the Forestry SA data and verified with industry partners.

**Table 12: Assumed production costs used in modelling pine plantation economics**

| | |
|---|---|
| **Site preparation ($/ha)** | 200 |
| **Planting costs ($/ha)** | 673 |
| **2nd Year fertiliser ($/ha)** | 115 |
| **post thinning fertiliser ($/ha)** | 207 |
| **Annual Maintenance ($/ha)** | 50 |
| | |
| **Assumed planting density (stems/ha)** | 1600 |

### Discount rate

Data on the discount rates used in corporate forestry investments is not specifically available and can be difficult to quantify. However, Ferguson (2018) and Manley (2016) show that real discount rates use in forest valuation can vary considerably from between 5 percent to 14 percent. We chose to use a real discount of 7.5 percent reflecting a cost of capital of 10 percent and an inflation rate of 2.5 percent which approximates the annual average consumer price index in Australia between 2010-2017 (Glassock, 2018).

# Forest valuation

The valuation of hardwood and softwood plantations was done with the same methodology. It involved the following steps:

1. Valuation of existing forest stands (NPV) for various rotation lengths. I.e. 10-15 years for hardwoods, 32- 40 years for softwoods.
2. Calculate the land expectation value of continuing in forestry after current stand is harvested.
3. Value land use alternatives and potential water sales
4. Optimise economic valuation of operation.

In order to prevent repetition, the following outlines 1-4 in detail using hardwoods as the case study.

## NPV of existing forest stands

The first step is to calculate the net present value for plantations already established and in the ground.

Functionally, the NPV of any current established forestry plantation $f$ can be expressed as

$$NPV_f = PVR_f - PVC_f \quad (1)$$

Where $PVR_f$ is the present value of revenues from any forestry stand $f$ and $PVC_f$ is the present value of costs from any forest stand $f$.

However, this form would apply to forest stands that are yet to be established and where the rotation length is known. In reality, the rotation length for hardwood stands are highly variable and depend on multiple factors including commodity price and contractual arrangements. As such the rotation length may vary from between 10 and 15 years (hardwoods), resulting in varying harvest volumes, $HV$. In addition, the current age, $a$, of any forest stand $f$ will be theoretically distributed between 1 and 14 years old. Therefore, the NPV of an existing forest stand $f$ will be determined by the rotation length $r$ selected and current age $a$ of the existing forest stand.

$$PVR_{f,r,a} = \frac{HV_r \times P}{(1+i)^{(r-a)}} \quad (2)$$

Where $P$ is the wood chip price and the term $i$ is the real discount rate.

For blue gum stands that are already established, previous costs associated with the establishment and maintenance of the stand are assumed sunk and do not enter into the calculation of financial returns form current forest operations.

The term $PVC_f$ in Equation 1 is the present value of all costs for forest stand $f$: it is calculated as:

$$PVC_{f,r,a} = \sum_{t=0}^{T} \frac{MC_t + FC_t + HC_t + TC_t + CC_t}{(1+i)^t} \quad (3)$$

Where $T$ is equal to the rotation length, $r$, minus the current age $a$ of forest stand $f$. $MC_t$ is the maintenance costs that occur in each year *t,* $FC_t$ is any fertiliser costs that occur in any year *t,* $HC_t$ is the harvest costs that occur in year *t* and $TC_t$ and $CC_t$ are the transport costs and other contractor costs that occur in each year *t.*

For blue gum stands that are already established, previous costs associated with the establishment and maintenance of the stand are assumed sunk and do not enter into the calculation of financial returns from current forest operations.

## Land Expectation Value

The land expectation value (LEV) is the present value of the costs and revenues resulting from a perpetual sequence of forestry rotations, starting initially from bare land. The LEV is standard forest industry practice for valuing bare land in timber production, evaluating the value of various forest management alternatives and determining the optimal rotation age (Faustmann, 1995). In this study the LEV is used to value the decision to continue in forestry after the existing forest stand is harvested.

The first step in determining the LEV is calculating the present value of the first rotation $PV_{R1}$. Similarly, to the calculation of remaining NPV the rotation length is unknown, so $PV_{R1}$ is calculated for all rotation lengths $r = 10$ to $r$ = 15.

$$PVR1_r = -Est + \sum_{t=1}^{r-1} \frac{I_t}{(1+i)^t} + \frac{A[(1+r)^r - 1}{i\,(1+i)^r} + \frac{\sum_{p=1}^{n} P_p\, Y_{p,r} - C_h}{(1+i)^r} \quad (4)$$

Where $Est$ are the establishment costs, $I_t$ are intermediate cost or revenue (i.e. thinning revenues), $A$ the net cost or revenue from all annual costs and benefits (I.e. maintenance cost), $P_p$ is the price of product $p$, $Y_{p,r}$ is the expected yield of product $p$ for rotation length $r$ and $C_h$is the cost associated with harvest (i.e. harvesting and transport).

The next step is to convert the present value of the first rotation into a future value:

$$FVR1_r = PVR1_r \times (1+i)^r \quad (5)$$

Finally, the LEV of each different rotation length $r$ is calculated by applying the infinite periodic payment formula;

$$LEV_r = \frac{FVR1_r}{(1+i)^r - 1} \quad (6)$$

However, if the land use remains in forestry then $LEV_r$ is being applied at the completion of an existing rotation not from time $t = 0$. As a result, *remaining* LEV, $RLEV_r$ is calculated;

$$RLEV_r = \frac{LEV_r}{(1+i)^{(r-a)}} \quad (7)$$

It is assumed that replanting will occur in the same year as harvest hence the term $r - a$ in the denominator of equation 7.

## Agricultural profitability

The third option available to the company is reconverting land back to an agricultural land use. The most immediately applicable option is to covert the previously forested area to pasture. Industry partners indicated land converted to agriculture is often leased and not operated as an agricultural enterprise by the company. As such an annual lease rate was modelling in place of other common measures of agricultural profitability, namely gross margins. Indicative agricultural land lease rates for the area were provided by industry and were assumes to be \$125/ha/year for in slow conversion option and \$250/ha/year for the fast conversion option. The sensitivity of results were tested to land lease rates in Section 0 (Table 4).

Similarly, to LEV for the forest land uses, we calculated the value of a conversion to agriculture as a perpetual annuity, or perpetuity. A perpetuity is a constant stream of identical cashflows and is calculated as:

$$PV_{Ag} = \frac{lease\ rate}{i} \tag{8}$$

As with forestry land uses described above, agricultural land use does not occur until after the completion of the existing hardwood rotation and as such the remaining perpetuity of agriculture $RPV_{Ag}$ is calculated in the same fashion as the remaining LEV, $RLEV_r$, in equation 7.

There are also reconversion costs $RC_{Ag}$ to consider (**Error! Reference source not found.**) and these are subtracted from the remaining perpetuity of agriculture $PV_{Ag}$ . We assume that reconversion costs occur in the same year as the harvest of the hardwood stand, however grazing cannot occur until the following year to allow for pasture regeneration. As such a fallow cost, $FAC$, is incurred that represents the opportunity cost of the land being idle for the one-year reconversion period.

As such the remaining perpetuity of agriculture $RPV_{Ag}$ is calculated as;

$$RPV_{Ag} = \frac{PV_{Ag}}{(1+i)^{(r-a+2)}} - \frac{RC_{Ag}}{(1+i)^{(r-a)}} - \frac{FAC}{(1+i)^{(r-a+1)}} \tag{9}$$

We also model a slow reconversion option $RC_{Ag}^{slow}$ , an option that is of interest to industry. In this scenario less money is invested upfront in reconversion, however it takes longer (4 years) for the land to be in agricultural production. In this instance the remaining perpetuity of agriculture $PV_{Ag}^{Slow}$ is calculated

$$RPV_{Ag}^{Slow} = \frac{PV_{Ag}}{(1+i)^{(r-a+5)}} - \frac{RC_{Ag}^{slow}}{(1+i)^{(r-a)}} - \sum_{t}^{T} \frac{FAC}{(1+i)^{t}} \tag{10}$$

Where $t = r - a + 1$ and $T = r - a + 1.5$

## Water sale

The fourth option available to the company is to sell the water allocations post-harvesting the existing blue gum stands. In this instance water would be sold and the land reconverted to a dryland agriculture use as outlined in Equation 8 and Equation 9. The LLC has significant irrigated agricultural, horticultural and viticulture industries and as such water markets exist which allow the temporary or permanent trade of water allocations. However, compared to more established irrigation areas, for example in the Murray- Darling Basin, volumes are generally low ranging between 2000 – 5000 ML/month. Permanent water allocations can trade for in excess of $7500/ML in a dry year (Waterfind, 2019), however more routinely range from between $600 – $1100/ML (Waterfind, 2019).

As the sale of water will occur after the harvest of the current rotation, returns from the sale of water allocations are likely to occur at a point several years in the future. As such revenue from water sales ($Wrev$ ) are calculated similarly to returns from a conversion to pine or agriculture;

$$Wrev_f = \frac{Wvol * Wprice}{(1+i)^{(r-a)}} \tag{11}$$

Where $Wvol$ is the volume of water in ML being sold and $Wprice$ is the price of permanent water allocations in $/ML.

Post water sale the land is assumed to be converted to dryland agriculture and returns calculated as outlined in Section 9.1.3. As such total returns from the sale of a water allocation ($Wsale$) is calculated as;

$$Wsale_f = \; Wrev_f + m \qquad\qquad m = \begin{cases} RPV_{Ag}^{Slow} \\ RPV_{Ag} \end{cases} \tag{12}$$

# References


ABARES, 2018a. Australia's State of the Forests Report 2018. Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

ABARES, 2018b. Forests of Australia (2018) dataset, Canberra, https://www.agriculture.gov.au/abares/forestsaustralia/forest-data-maps-and-tools/spatial-data/forest-cover

ABS, 2020. Value of Agricultural Commodities Produced, Australia: 2018-19 Canberra, Accessed via: https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/7503.02018-19?OpenDocument

DEW, 2009. Soil and land attributes, Adelaide, Accessed via: https://data.sa.gov.au/data/dataset/soil-groups

DEW, 2017. Groundwater interception likelihood Adelaide, Accessed via: https://data.sa.gov.au/data/dataset/carbon-planting-in-sa

DEW, 2019. Water Allocation Plan for the Lower Limestone Coast Prescribed Wells Area. Department for Environment and Water, Adelaide.

Faustmann, M., 1995. Calculation of the value which forest land and immature stands possess for forestry. Journal of Forest Economics

Ferguson, I., 2018. Discount rates for corporate forest valuations. Australian forestry 81, 142-147.

Glassock, A., 2018. 70 Years of Inflation in Australia. Australian Bureau of Statistics, Canberra.

GTFIH, 2021, Green Triangle Forest Industries Hub., Accessed via :https://www.gtfih.com.au/forestry-in-the-green-triangle/

KPMG, 2018. Australian pine log price index (stumpage). KPMG.

Leech, J., 2003. Consultancy to develop and growth and yield model for E. globulus for Forestry South Australia. Forestry South Australia, Adelaide.

Lewis, N.B., Keeves, A., Leech, J., 1976. Yield regulation in South Australian Pinus radiata plantations. Yield regulation in South Australian Pinus radiata plantations.

Manley, B., 2016. Discount rates used for forest valuation–results of the 2015 survey. NZ Journal of Forestry 61, 29.

Schirmer, J., Loxton, E., Campbell-Wilson, A., 2008. Monitoring the social and economic impacts of forestry: A case study of the Green Triangle. DAFF.

SENRMB, 2013. Protecting vulnerable water resource. South East Natural Resource Management Board, Adelaide.

SENRMB, 2019. Water Allocation Plan for the Lower Limestone Coast Prescribed Wells Area. South East Natural Resource Management Board, Adelaide.

Von Bertalanffy, L., 1949. Problems of organic growth. Nature 163, 156-158.

WaterConnect, 2020, Department for Environment and Water, Accessed via: https://www.waterconnect.sa.gov.au/Systems/WTR/Pages/Default.aspx

Waterfind, 2019. Australian water markets annual report, Adelaide.