Appendices

Appendices are numbered in alignment with the section numbers of the main report.
A1. Introduction

A1.2 System of Environmental Economic Accounting

References providing additional guidance to the SEEA include:

- General guidance – SEEA Implementation Guide (UNSD 2014c)
- Water – SEEA Water (UNSD 2012a) and International Recommendations for Water Statistics (UNSD 2012b), Guidelines for the Compilation of Water Accounts and Statistics (UNSD 2014d)
- Forests (Castañeda 2016)
- SEEA-Agriculture, Forestry and Fisheries (FAO 2015)
- Ecosystem accounting (World Bank 2014)

Examples of application of the SEEA in Australia include:

- Australian Bureau of Statistics (ABS) (ABS 2015a)
- Government of Victoria (Eigenraam et al. 2013; Varcoe et al. 2015)
- Bureau of Meteorology (BoM) uses a system of water accounting (BoM 2014) that can be related to SEEA (Vardon et al. 2012)
- Wentworth Group of Concerned Scientists has developed a process and metrics for producing accounts (Sbrocchi 2015).

A number of accounts for specific assets or services already cover all or part of the Central Highlands region or the economic users of the region, including:

- Land Accounts Victoria, Experimental Estimates (ABS 2013)
- Water Accounts, Australia (ABS 2015)
- National Water Account – Melbourne (BoM 2014)
- State Tourism Satellite Accounts (TRA 2015)
- Value of Tourism to Victoria’s Regions (Tourism Victoria 2015)
- Victorian Experimental Ecosystem Accounts (Eigenraam et al. 2013)
- Valuing Victoria’s Parks (Varcoe et al. 2015)
- Melbourne Water Annual Reports
- VicForests Annual Reports.

General outcomes from accounts, both actual and potential, are covered in the documents of the SEEA Applications and Extensions (European Commission et al. (2014), Smith (2014) and Vardon et al. (2012)).

There is also a growing Australian literature on ecosystem services (Crossman et al. 2013; Stoeckl et al. 2011; Tovey 2008; Straton and Zander 2009).
A2. Accounting methods

A2.3 Classifications

Definitions of industry classifications according to the Australia New Zealand Standard Industry Classification (ANZSIC 2016) (ABS and SNZ 2006), together with additional notes to assist interpretation of the report.

**Division A: Agriculture, Forestry and Fishing**

*The Agriculture, Forestry and Fishing Division includes units mainly engaged in growing crops, raising animals, growing and harvesting timber, and harvesting fish and other animals from farms or their natural habitats. The division makes a distinction between two basic activities: production and support services to production. Included as production activities are horticulture, livestock production, aquaculture, forestry and logging, and fishing, hunting and trapping.*

*The term ‘agriculture’ is used broadly to refer to both the growing and cultivation of horticultural and other crops (excluding forestry), and the controlled breeding, raising or farming of animals (excluding aquaculture).*

*Aquacultural activities include the controlled breeding, raising or farming of fish, molluscs and crustaceans.*

*Forestry and logging activities include growing, maintaining and harvesting forests, as well as gathering forest products.*

*Fishing, hunting and trapping includes gathering or catching marine life such as fish or shellfish, or other animals, from their uncontrolled natural environments in water or on land.*

*Also included in the division are units engaged in providing support services to the units engaged in production activities.* *(ABS and SNZ 2006, p. 66)*

Within Division A, the Subdivisions of relevance for this report are 01 Agriculture and 03 Forestry and Logging. In particular, VicForests is part of the Subdivision 03 Forestry and Logging.

**Division D: Electricity, Gas, Water and Waste Services**

*The Electricity, Gas, Water and Waste Services Division comprises units engaged in the provision of electricity; gas through mains systems; water; drainage; and sewage services. This division also includes units mainly engaged in the collection, treatment and disposal of waste materials; remediation of contaminated materials (including land); and materials recovery activities.*

*Electricity supply activities include the generation, transmission and distribution of electricity and the on-selling of electricity via power distribution systems operated by others.*

*Gas supply includes the distribution of gas, such as natural gas or liquefied petroleum gas, through mains systems.*

*Water supply includes the storage, treatment and distribution of water; drainage services include the operation of drainage systems; and sewage services include the collection, treatment and disposal of waste through sewer systems and sewage treatment facilities.* *(ABS and SNZ 2006, p. 68)*

Within Division D, the Subdivision Water Supply, Sewerage and Drainage Services is the area of interest, with Melbourne Water coded to this Subdivision.

**Other ANZIC industries**

Other Divisions to note are: **Division C: Manufacturing**, which includes Food Product Manufacturing (Subdivision 11), Beverage and Tobacco Product Manufacturing (Subdivision 12), Wood Product Manufacturing (Subdivision 14), and Pulp, Paper and Converted Paper Product Manufacturing (Subdivision 15); and **Division R: Arts and Recreation Services** which includes the operation of National Parks (Subdivision 892 Parks and Garden Operations).

**Division C: Manufacturing** will use inputs from **Division A: Agricultural, Forest and Fishing**. The distinction is important as in other contexts the Agriculture Industry or the Forest Industry are defined to include the transformation of the primary products into manufactured goods (e.g. grapes processed into wine, or woodchips into paper). This report does not take this approach and uses the ANZSIC definition of Agriculture and Forestry.

**Tourism**

Tourism is not defined in ANZSIC but in a satellite accounting framework of the System of National Accounts (ABS 2016d), and additional information on the definition of tourism is found in the Explanatory Notes of the ABS (2016d) Tourism Satellite Account.
A3. Land

A3.1 Spatial data sources

LAND COVER


These were subsequently modified on public land by the more detailed forest type information in the 2013 version of State-wide Forest Resource Inventory (SFRI) data, ‘SFRITrev2013’ (http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803002820&publicId=guest&extractionProviderId=1), where available, and by plantation information in the 2015 version of Forest Management Zone (FMZ) data, ‘FMZ100’ (http://www.giconnections.vic.gov.au/content/vicgdd/record/ANZVI0803002608.htm).

Then, ‘Land Cover’ classes on private land were adjusted using land cover and land use classes in several versions of the Victorian Land Use Information System

Finally, water, road and structure classes in these data, overwrote any previous allocations on all land.

LAND USE

‘Land Use’ classes were allocated on public land by grouping classes in the 2015 version of Forest Management Zone (FMZ) data, ‘FMZ100’ http://www.giconnections.vic.gov.au/content/vicgdd/record/ANZVI0803002608.htm

Private land was grouped by classes in the 2014/2015 version of Victorian Land Use Information System.

LAND MANAGEMENT

We used the 2015 version of ‘PLM25’ (https://www.data.vic.gov.au/data/dataset/public-land-management-plm25), which describes public land management, where Public Land is defined as land held by/ vested in/or owned by DELWP and other government departments, public authorities, Commonwealth government and municipalities.

FIRE HISTORY

We used the 2015 version of ‘FIRE_HISTORY’ (https://www.data.vic.gov.au/data/dataset/fire-history-records-of-fires-primarily-on-public-land) which represents the spatial extent of fires recorded since 1903 primarily on public land, and is attributed for wildfire and prescribed burn. The assumption was made that wildfires result in regeneration of ash forests and rainforest. However, additional fire severity information was available for the 2009 wildfires.
For these fires, regeneration was only assumed for the two most severe classes – Crown Burn and Crown Scorch.

LOGGING HISTORY

We used the 2015 version of ‘LASTLOG25’ http://services.land.vic.gov.au/catalogue/metadata?anzlicId=ANZVI0803002521&publicId=guest&extractionProviderId=1
A coupe-based logging history overlay of most recent harvesting activities, attributed by time period and silvicultural method. Harvesting, other than ‘Thinning from Below’ and ‘Single Tree Selection’ was assumed to result in forest regeneration.

OLD GROWTH FOREST

A3.5 Anomalies in land classification

Examples of anomalies in the land classification systems.

Example 1. Incorrect coding in one year.

Figure A3.1. Land use classification showing three anomalies in the coding for areas of ‘conservation’. The areas marked as ‘conservation’ in only one year (1. in 2012, 2. and 3. in 2014) had not changed the land use category in reality, but had been coded incorrectly.
Example 2: Change in definition of the classification criteria in one year.

Figure A3.2. Land use classification showing an anomaly in the criteria for ‘residential’. In 2012 there was a larger area of ‘residential’ than in 2010 or 2014, which would not have occurred in reality.
Example 3. Inconsistency in boundaries between different spatial layers of land cover.

![Map showing boundaries between different spatial layers of land cover.]

Legend
- Native woody cover
- bare
- built-up area
- crop
- eucalypt plantation
- horticulture
- montane ash
- montane woodland
- open mixed forest
- open water
- pasture/grassland
- pine plantation
- rainforest
- riparian shrubs
- shrub and heath
- swamp
- wet mixed forest
- woodland

Figure A3.3. Native vegetation and managed vegetation area based on different spatial layers, and in this case the boundaries of the pine plantation do not match that of the native vegetation.

Example 4. Different sources of spatial data cause problems due to scale and aggregation.

![Map showing land cover and land use areas.]

Areas calculated for land cover and land use include:

Land cover:
- A: forest – 39.0 ha
- B: water – 3.5 ha
- C: residence – 1.8 ha
- D: irrigated crop – 13.5 ha
- E: other crop – 3.8 ha
- F: grassland – 68.0 ha

Land use:
- Agriculture (grazing) – 129.6 ha

Figure A3.4. Land cover is assessed from satellite images whereas land use is mapped using administrative data.
Example 5. Anomalies between land cover and land use classifications.

Figure A3.5. Classes that should be the same in both the land cover and land use classification systems sometimes do not correspond. ‘Horticulture’ is the same class but there are two areas on the west boundary that show a ‘horticulture’ land use but not land cover (circled in red). ‘Built-up area’ land cover should correspond to ‘residential’ and ‘commercial’ land use, all shown in shades of grey. However, there is more grey area for land use than for land cover, particularly in the central section of the map.
## A4. Water

### A4.2 Water asset account

Table A4.1. Central Highlands water asset account for the reservoirs from 1990 – 2015.

Stocks are the water storage within the 10 reservoirs managed by Melbourne Water and sourced from runoff within the study area. Precipitation and evaporation refer to the transfers from the surface water of the reservoirs. Data are not available for all components of a full water asset account and these amounts are included in the unaccounted changes. See table on next page.

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A4.3 Water Yield

A4.3. Background

The response of water yield to forest age was derived from a synthesis of information from the literature. Disturbance within a forested catchment results in increased runoff due to loss of leaf area in the short-term of up to 1 to 5 years, until leaf area is restored. Reported increases in runoff after a range of disturbance events range from 25 to 100% (Jayasuriya et al. 1993; Vertessy et al. 1996, 2001; Watson et al. 1999a, 2001; Lane et al. 2006, 2010; Feikema et al. 2006, 2013). The water yield response immediately post-disturbance is highly dependent on the soil moisture conditions pre- and post-disturbance. Increased runoff post-fire is diminished if initial soil moisture stores are low and if subsequent rainfall is low. Such dry conditions typically occur prior to major fires and were particularly the case in 2009, where there was no clear evidence of an increase in post-fire runoff (Tan et al. 2011). This is also likely the reason that Kuczera (1987) did not report an increase in flow after the 1939 fire, which occurred during a prolonged dry period. A post-disturbance increase in streamflow is more likely after harvesting and if rainfall conditions and soil moisture storage are average or above average.

In many ecosystems, there is a gradual return of runoff to pre-disturbance levels as leaf area is restored. However, in the montane ash forest there is an additional factor: the regenerating forest with dense leaf growth results in high water use by transpiration and hence reduced runoff. The pattern of response of water yield is well established, but the parameters describing magnitude and timing are variable (Langford 1976, Kuczera 1985, 1987, Vertessy et al. 2001, Buckley et al. 2012). The hydrological effects of forest age have been related to the hydraulic and structural characteristics of ash stands, such as age-dependent trends in leaf area index, leaf conductance, interception and sapwood area index. Kuczera (1987) developed a model of the catchment level response of water yield to large-scale disturbance in ash forest, that is, a stand-replacing event. Reductions in water yield were projected to commence about 3 years post-disturbance, reach a maximum in 20 - 30-year-old stands, and then decline as the forest aged and transpiration and interception declined. The gradual recovery of water yield may take about 150 to 200 years (Vertessy et al. 1998, 2001). The Kuczera model provides a general response of water yield to disturbance over time that is appropriate to apply at the regional scale. The general relationship and the magnitude of the parameters have been verified by studies of smaller paired catchment silvicultural treatment experiments and re-analysis of longer time periods of the streamflow data (Vertessy et al. 1998; Watson et al. 1999b; Brookhouse et al. 2013), and in other eucalypt forest types (Cornish and Vertessy 2001). At smaller scales, there are large variations in water yield between catchments with different site and forest characteristics and high levels of uncertainty in predictions of the recovery of water yield (Vertessy et al. 1998). Detailed prediction of impacts on water yield at the small catchment scale can be made using physically-based models that predict forest regrowth and its interactions with the water and energy balances given local site characteristics (Vertessy et al. 1996, Watson et al. 1999a, b).

A4.3.2 Calculations

Water yield with and without disturbance, and the resulting changes in forest age, was calculated for each grid cell in the study area. Alpine Ash, Mountain Ash and rainforest forest types that were clearfell logged or burnt (fire severity class 1 or 2 assessed in 2009) had an initial increase in runoff followed by a decrease related to forest age. Mixed species forest types that were clearfell logged had an initial increase in runoff, but then, were assumed to have constant leaf area (Feikema et al. 2006; Lane et al. 2010). Percent changes in water yield in relation to forest age of ash were applied to the annual runoff calculated from the water balance model. Two equations were used to describe the relationship between reduction in water yield and forest age, depending on the assumed initial or pre-disturbance forest age of either old growth or regrowth. The Kuczera (1987) model assumed the initial forest was old growth and was calibrated before the 1939 fire. Whereas, the current forest is mostly regrowth since the 1939 fire, and hence, is assumed to be experiencing reduced water yield. The water balance model was calibrated for the current forest, which meant that at the time of each disturbance event the current forest age was used in the calculations, the modelled water yield would have been less than the maximum, and hence the corresponding reduction in the regenerating forest would be less than that modelled.

The following functions were used in the calculation of water yield (shown in Figure A4.1):

- Initial increase in water yield following disturbance as a proportion of the baseline calculation for constant age:
  - Year 1 = +0.5; Year 2 = + 0.25; Year 3 = 0.

- Reduction in water yield as a proportion of the baseline calculation for constant age:
  - Pre-disturbance forest of old growth:
    - reduction proportion = 0.48 * 0.04167 * (t - 3) * exp(1 - 0.04167 * (t - 3))
  - Pre-disturbance forest of regrowth:
    - reduction proportion = 0.48 * 0.03667 * (t - 3 + 4.82) * exp(1 - 0.03665 * (t - 3 + 4.82)) + 0.1949
Figure A4.1. Change in water yield following stand-replacing disturbance in montane ash forest calculated for old growth forest and 75-year-old regrowth.

Source: Kuczera (1987) for old growth model

An initial increase in water yield occurs and then a decrease over time under the regrowing forest. Pre-disturbance conditions of 75-year-old regrowth and old growth forest are compared.

A4.3.3 Results

The water yield for the combined catchments within in the study area is shown in Figure A4.2, together with the difference in yield due to the reduction resulting from forest age using conditions of the initial forest being old growth or regrowth. Using a pre-disturbance vegetation condition of the 75-year old regrowth is probably the most realistic scenario for this region because the majority of the forest was burnt in 1939. Pre-disturbance condition of regrowth produces a lesser reduction because the catchment was not at maximum water yield at the time that the disturbances occurred. The difference between constant forest age and the regrowth and old growth conditions are reduced over time as the forest increases in age.

Figure A4.2. Total annual water yield for the reservoirs in the Central Highlands showing the difference in yield resulting from different initial conditions of forest age, being either constant, old growth or regrowth.
Water yield reflects the area of the catchment, but also the water balance between precipitation and evaporation, and the effect of vegetation type and slope on runoff. For example, the O’Shannassy, Maroondah and Tarago catchments are similar sizes (Table A4.2), but the water yield is greatest in the O’Shannassy and least in the Tarago. The catchments differ greatly in their proportions of different land cover types (Table A4.2 and Figure A4.2), and this influences the response of water yield because the reduction due to forest age is applied to the Mountain Ash, Alpine Ash and rainforest land cover types, but not to the mixed forest and woodland types. The proportion of each catchment that has regenerating forest following disturbance by wildfire or logging over the period 1970 – 2012 is shown in Figure A4.3. The largest catchment, the Thomson, had 9% of the area logged in ash forest representing 4300 ha, which was a similar area to that burnt in 2009 in the O’Shannassy catchment.

<table>
<thead>
<tr>
<th>Reservoir catchment</th>
<th>Mountain &amp; Alpine Ash, Rainforest</th>
<th>Open &amp; wet mixed forest, woodland, montane woodland</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>area (ha)</td>
<td>%</td>
<td>area (ha)</td>
<td>%</td>
</tr>
<tr>
<td>Upper Yarra</td>
<td>16,271</td>
<td>48</td>
<td>16,853</td>
<td>50</td>
</tr>
<tr>
<td>Maroondah</td>
<td>7,473</td>
<td>73</td>
<td>2,461</td>
<td>24</td>
</tr>
<tr>
<td>O’Shannasssuy</td>
<td>11,394</td>
<td>96</td>
<td>444</td>
<td>4</td>
</tr>
<tr>
<td>Thomson</td>
<td>16,781</td>
<td>35</td>
<td>27,380</td>
<td>58</td>
</tr>
<tr>
<td>Tarago</td>
<td>4,949</td>
<td>43</td>
<td>3,798</td>
<td>33</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure A4.3. Proportion of the catchment area that is regenerating forest following wildfire or logging in ash forest, and logging in mixed species forest, over the period 1970 to 2012.
Figure A4.4. Annual water yield in the five catchments of the Central Highlands study area over the period 1970 to 2012, using a baseline of regrowth forest.

The effect of the water yield reduction depends on the age of the montane ash forest and rainforest, and the area of these forest types within each catchment. The shift in age categories over time due to fire or logging is shown in the following graphs and maps. The age categories were selected to coincide with similar proportions of water yield reduction, with the greatest reduction occurring between ages of 13 – 49 years and peaking at 25 years. Forest age is determined from the last stand-replacing event, which refers to fire or clearfell logging for ash, and clearfell logging for mixed species forest.

Figure A4.5. Distribution of forest types across the catchments, where montane ash type forest and rainforest are affected by reduction in water yield and mixed forest is not affected.
Figure A4.6. The proportion of catchment area in each forest type and age category, which determine the reduction in the water yield function. Shown at time intervals of 1974, 1980, 1999 and 2012 to provide an estimate of change over time.
Figure A4.7: Spatial distribution of forest age categories shown for a selection of years to illustrate the change over time, both as forests increase in age and disturbance results in regeneration of young forest.
Figure A4.7. (continued) Spatial distribution of forest age categories shown for a selection of years to illustrate the change over time, both as forests increase in age and disturbance results in regeneration of young forest.

The reduction in water yield due to forest age is declining in all catchments over the period 1970 to 2012, because the majority of the forest is 1939 regeneration, which is increasing in age (Figure A4.8). Differences between the catchments in their rate of change reflect the factors that reduce water yield. The greatest rate of decline in the reduction of water yield, that is, the greatest rate of return of water yield to pre-disturbance levels, occurs in the O’Shannassy catchment. This catchment has the highest proportion of montane ash forest and had no stand-replacing disturbances, until the 2009 fire. The Maroondah catchment is similar but with a lower proportion of ash forest.
The Tarago and Thomson catchments have a smaller proportional reduction in water yield than other catchments, because they have more mixed species forest where the regrowth does not cause the reduction in water yield. These two catchments have more logged areas and hence younger forest, but less of this forest is ash, than in the other catchments. The Tarago catchment does not show a decline from 2004 to 2009, which may indicate reductions in yield due to younger forest regenerating from logging.

The increases in water yield in 2010 and 2011 in the O’Shannassy and Tarago catchments reflect the large areas burnt in 2009 and the short-term increase in runoff after fire. This result may be an over-estimate of the increase in runoff after disturbance, because the increase may not have been as large as that described by the standard function due to the dry conditions before and after this fire.

Figure A4.8. Reduction in water yield from constant forest age assuming regrowth forest baseline

The difference in water yield for the counterfactual case with no logging in the catchments was calculated using the response function of water yield in regenerating forest. The assumption about an initial increase in runoff following disturbance until leaf area is restored depends on the antecedent soil water content and post-disturbance weather conditions, which influence the proportion of rainfall that infiltrates the soil. The effect of this assumption on water yield is shown in Figure A4.9.

Figure A4.9. Difference in water yield for the counterfactual case with no logging in the catchments, showing the effect of the assumption about an initial increase in runoff post-disturbance
A5.2 Carbon stock assets

A5.2.1.1 Carbon stocks in land cover types

The biomass carbon stock model was derived for montane ash forest, but the carbon stock in mixed species wet temperate forest is less than for the ash forest. This adjustment in the modelled carbon stock was estimated using existing allometric volume equations and wood density for the other species compared with the ash species (Keith et al. 1997, 2000; Bi et al. 2004; Illic et al. 2000). Estimates of biomass carbon stock density for other land cover types were derived from the best available information in the literature, and were applied as constant values. Carbon stocks in eucalypt and pine plantations were calculated using the FullCAM model with standard plot values for the region (DotE 2015).

Table A5.1 Estimates of biomass carbon stock density for all land cover types in the study area

<table>
<thead>
<tr>
<th>Land cover</th>
<th>Average carbon stock (tC ha⁻¹)</th>
<th>Proportion of modelled ash</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocky / bare</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Riparian shrubs</td>
<td>40</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rainforest</td>
<td>325</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Wet mixed forest</td>
<td>0.6</td>
<td>3, 4, 5, 6, 7</td>
<td></td>
</tr>
<tr>
<td>Montane ash forest</td>
<td>1.0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Open mixed forest</td>
<td>0.5</td>
<td>5, 6, 7</td>
<td></td>
</tr>
<tr>
<td>Woodlands</td>
<td>150</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Shrub and heath</td>
<td>30</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Swamp</td>
<td>20</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Montane woodland</td>
<td>150</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Grazing</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cropping</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Horticulture</td>
<td>8</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Plantation softwood</td>
<td>56</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Plantation hardwood</td>
<td>152</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Residential</td>
<td>15</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Reservoirs</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>


A5.2.1.2 Carbon accumulation functions

Table A4.2. Carbon accumulation functions based on forest growth for each forest type

t is the time since the last stand-replacing disturbance event

<table>
<thead>
<tr>
<th>Forest type</th>
<th>Carbon accumulation function</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montane ash</td>
<td>1200 x (1-exp(-0.0045 t)⁰⁷)</td>
<td>1</td>
</tr>
<tr>
<td>Wet mixed species</td>
<td>450 x (1-exp(-0.015 t)¹⁰⁵)</td>
<td>3, 4, 5, 6, 7</td>
</tr>
<tr>
<td>Open mixed species</td>
<td>310 x (1-exp(-0.025 t)¹¹⁴)</td>
<td>5, 6, 7</td>
</tr>
<tr>
<td>Rainforest</td>
<td>800 x (1 - exp(-0.002 t)¹⁴²)</td>
<td>11, 12</td>
</tr>
<tr>
<td>Pine plantation</td>
<td>130 x (1 - exp(-0.15 t)⁶)</td>
<td>7</td>
</tr>
<tr>
<td>Eucalypt plantation</td>
<td>500 x (1-exp(-0.35 t)¹²⁵)</td>
<td>7</td>
</tr>
<tr>
<td>Woodland</td>
<td>C₄₃ + 0.23</td>
<td>11</td>
</tr>
</tbody>
</table>

A5.2.1.3 Change in carbon stock due to logging

Equations describing the reduction in carbon stock due to logging of the majority of biomass, based on Keith et al. (2014a).

Amount of biomass remaining on-site after product removal from logging:
\[ C_{\text{slash}} = 0.6 \times C_{\text{initial}} \]

Amount of biomass remaining on-site after slash burning:
\[ C_{\text{residual}(0)} = 0.5 \times C_{\text{slash}} \]

Decomposition of the residual biomass remaining after harvesting and slash burning:
\[ C_{\text{residual}(t)} = C_{\text{residual}(0)} \times \exp(-0.07 \ t) \]

Reduction in carbon stock due to selective logging, including single tree selection and thinning, were based on information about silvicultural systems and proportion of basal area removed (Florence 1996, Lutze et al. 1999, Flinn et al. 2007). Single-tree selection and thinning from above were estimated as a reduction by 50%, and thinning from below as a reduction by 30%. Selective harvesting and single-tree selection are described as the removal of mature trees only and leaving immature trees for harvesting in the future (VAGO 2013). Thinning removes some trees to increase the health and growth rate of the remaining trees or to access timber from trees before they die (VAGO 2013). Stems removed can be mature trees and merchantable species for timber, over-mature trees to provide space for growing stock, or small trees or non-merchantable species to reduce competition with growing stock. Hence, these silvicultural systems are highly variable in terms of biomass removed and effect on forest age structure.

A5.2.1.4 Change in carbon stock due to fire

Equations describing the change over time in dead biomass components after fire, based on Keith et al. (2014b).

Dead standing trees remain after fire, but slowly collapse and fall to the ground.
\[ C_{\text{dead_standing}(t+1)} = C_{\text{dead_standing}(t)} / (1 + \exp(0.1 \ t - 5)) \]

Fallen trees become input to the coarse woody debris (CWD).
\[ C_{\text{dead_standing}(t)} - C_{\text{dead_standing}(t+1)} = C_{\text{CWD_input}} \]

Coarse woody debris on the ground decomposes over time.
\[ C_{\text{CWD}(t)} = C_{\text{CWD}(0)} \times \exp(-0.07 \ t) + C_{\text{CWD_input}} \]

### Table A4.3. Loss in biomass carbon stock (%) due to emissions under different fire severities

<table>
<thead>
<tr>
<th>Forest age (yrs)</th>
<th>Fire severity</th>
<th>Low (classes 3 ,4 ,5)</th>
<th>High (classes 1, 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 30</td>
<td></td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>31 – 72</td>
<td></td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>&gt; 72</td>
<td></td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

If fire severity was not known, an average of 10% carbon stock loss due to emissions was used. (Keith et al. 2014b).
### A6. Plantation Timber

**Table A6.1.** Australian forestry and logging industry, estimated resource rent, 2006-07 to 2013-14 ($m current prices)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total industry output (Australian production)</td>
<td>$3,075</td>
<td>$3,406</td>
<td>$3,363</td>
<td>$3,732</td>
<td>$3,354</td>
<td>$3,262</td>
<td>$3,043</td>
<td>$3,632</td>
</tr>
<tr>
<td>less</td>
<td>Intermediate consumption</td>
<td>$2,264</td>
<td>$2,542</td>
<td>$2,417</td>
<td>$2,477</td>
<td>$1,647</td>
<td>$1,907</td>
<td>$1,681</td>
</tr>
<tr>
<td></td>
<td>Compensation of employees</td>
<td>$555</td>
<td>$524</td>
<td>$648</td>
<td>$618</td>
<td>$595</td>
<td>$516</td>
<td>$491</td>
</tr>
<tr>
<td></td>
<td>Net taxes on production</td>
<td>$21</td>
<td>$30</td>
<td>$21</td>
<td>$16</td>
<td>$34</td>
<td>$20</td>
<td>$-8</td>
</tr>
<tr>
<td>equals</td>
<td>Gross operating surplus &amp; mixed income</td>
<td>$235</td>
<td>$310</td>
<td>$278</td>
<td>$621</td>
<td>$1,078</td>
<td>$819</td>
<td>$879</td>
</tr>
<tr>
<td>less</td>
<td>Consumption of fixed capital</td>
<td>$122</td>
<td>$150</td>
<td>$121</td>
<td>$281</td>
<td>$429</td>
<td>$321</td>
<td>$320</td>
</tr>
<tr>
<td></td>
<td>Return to fixed capital</td>
<td>$83</td>
<td>$101</td>
<td>$73</td>
<td>$154</td>
<td>$252</td>
<td>$112</td>
<td>$146</td>
</tr>
<tr>
<td>equals Resource rent</td>
<td>$30</td>
<td>$59</td>
<td>$84</td>
<td>$186</td>
<td>$397</td>
<td>$386</td>
<td>$413</td>
<td>$514</td>
</tr>
<tr>
<td>Resource rent % of total industry output</td>
<td>1.0%</td>
<td>1.7%</td>
<td>2.5%</td>
<td>5.0%</td>
<td>11.8%</td>
<td>11.8%</td>
<td>13.6%</td>
<td>14.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Net Present Value</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Capital Stock at beginning of year</td>
<td>$1,320</td>
<td>$1,570</td>
<td>$1,319</td>
<td>$3,010</td>
<td>$4,835</td>
<td>$3,698</td>
<td>$3,884</td>
<td>$5,836</td>
</tr>
<tr>
<td>Rate of Return on capital (RBA 10yr Bond-Rate)</td>
<td>6.26%</td>
<td>6.45%</td>
<td>5.52%</td>
<td>5.10%</td>
<td>5.21%</td>
<td>3.04%</td>
<td>3.76%</td>
<td>3.54%</td>
</tr>
<tr>
<td>Discount Rate</td>
<td>6.26%</td>
<td>6.45%</td>
<td>5.52%</td>
<td>5.10%</td>
<td>5.21%</td>
<td>3.04%</td>
<td>3.76%</td>
<td>3.54%</td>
</tr>
</tbody>
</table>

**Table A6.2.** Central Highlands forestry and logging industry, estimated resource rent, 2006-07 to 2013-14 ($m current prices)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total industry output (Central Highlands)</td>
<td>$16.76</td>
<td>$16.05</td>
<td>$17.94</td>
<td>$18.69</td>
<td>$27.54</td>
<td>$39.61</td>
<td>$52.04</td>
<td>$64.07</td>
</tr>
<tr>
<td>less</td>
<td>Intermediate consumption</td>
<td>$12.33</td>
<td>$11.98</td>
<td>$12.89</td>
<td>$12.41</td>
<td>$13.53</td>
<td>$23.16</td>
<td>$28.75</td>
</tr>
<tr>
<td></td>
<td>Compensation of employees</td>
<td>$3.02</td>
<td>$2.47</td>
<td>$3.46</td>
<td>$3.10</td>
<td>$4.89</td>
<td>$6.27</td>
<td>$8.40</td>
</tr>
<tr>
<td></td>
<td>Net taxes on production</td>
<td>$0.11</td>
<td>$0.14</td>
<td>$0.11</td>
<td>$0.08</td>
<td>$0.28</td>
<td>$0.24</td>
<td>$-0.14</td>
</tr>
<tr>
<td>equals</td>
<td>Gross operating surplus &amp; mixed income</td>
<td>$1.28</td>
<td>$1.46</td>
<td>$1.48</td>
<td>$3.11</td>
<td>$8.85</td>
<td>$9.95</td>
<td>$15.03</td>
</tr>
<tr>
<td>less</td>
<td>Consumption of fixed capital</td>
<td>$0.67</td>
<td>$0.71</td>
<td>$0.65</td>
<td>$1.41</td>
<td>$3.52</td>
<td>$3.90</td>
<td>$5.48</td>
</tr>
<tr>
<td></td>
<td>Return to fixed capital</td>
<td>$0.45</td>
<td>$0.48</td>
<td>$0.39</td>
<td>$0.77</td>
<td>$2.07</td>
<td>$1.37</td>
<td>$2.50</td>
</tr>
<tr>
<td>equals Resource rent</td>
<td>$0.17</td>
<td>$0.28</td>
<td>$0.45</td>
<td>$0.93</td>
<td>$3.26</td>
<td>$4.68</td>
<td>$7.06</td>
<td>$9.07</td>
</tr>
<tr>
<td>IVA</td>
<td>$4.42</td>
<td>$4.07</td>
<td>$5.05</td>
<td>$6.28</td>
<td>$14.01</td>
<td>$16.46</td>
<td>$23.29</td>
<td>$29.90</td>
</tr>
</tbody>
</table>
## A7. Agriculture

Table A7.1. Australian agriculture, estimated resource rent, 2006-07 to 2014-15 ($m current prices)

<table>
<thead>
<tr>
<th>SUBDIVISION 01 Agriculture</th>
<th>2008-09 $m</th>
<th>2009-10 $m</th>
<th>2010-11 $m</th>
<th>2011-12 $m</th>
<th>2012-13 $m</th>
<th>2013-14 $m</th>
<th>2014-15 $m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total industry output (Australian production)*</td>
<td>57,293</td>
<td>58,109</td>
<td>54,033</td>
<td>62,732</td>
<td>66,887</td>
<td>70,665</td>
<td>71,895</td>
</tr>
<tr>
<td>less Intermediate consumption</td>
<td>33,253</td>
<td>32,187</td>
<td>28,505</td>
<td>33,401</td>
<td>36,242</td>
<td>37,197</td>
<td>39,665</td>
</tr>
<tr>
<td>Compensation of employees</td>
<td>5,034</td>
<td>4,967</td>
<td>4,570</td>
<td>4,887</td>
<td>5,093</td>
<td>5,249</td>
<td>5,634</td>
</tr>
<tr>
<td>Net taxes on production</td>
<td>394</td>
<td>484</td>
<td>421</td>
<td>512</td>
<td>646</td>
<td>680</td>
<td>713</td>
</tr>
<tr>
<td>equals Gross operating surplus &amp; mixed income</td>
<td>18,612</td>
<td>20,471</td>
<td>20,537</td>
<td>23,932</td>
<td>24,906</td>
<td>27,539</td>
<td>25,883</td>
</tr>
<tr>
<td>less Consumption of fixed capital</td>
<td>9,013</td>
<td>8,941</td>
<td>9,287</td>
<td>9,532</td>
<td>9,762</td>
<td>10,039</td>
<td>10,145</td>
</tr>
<tr>
<td>Return to fixed capital</td>
<td>6,080</td>
<td>5,370</td>
<td>5,081</td>
<td>5,593</td>
<td>3,417</td>
<td>4,575</td>
<td>4,512</td>
</tr>
<tr>
<td>equals Resource rent</td>
<td>3,519</td>
<td>6,160</td>
<td>6,169</td>
<td>8,808</td>
<td>11,727</td>
<td>12,924</td>
<td>11,226</td>
</tr>
<tr>
<td>Resource rent % of total industry output</td>
<td>6.1%</td>
<td>10.6%</td>
<td>11.4%</td>
<td>14.0%</td>
<td>17.5%</td>
<td>18.3%</td>
<td>15.6%</td>
</tr>
</tbody>
</table>

### Net Present Value

- **Net Capital Stock at beginning of year**: 94,265, 97,290, 99,631, 107,343, 112,406, 121,678, 127,452 $m
- **Rate of Return on capital (RBA 10yr Bond-Rate)**: 6.45%, 5.52%, 5.10%, 5.21%, 3.04%, 3.76%, 3.54%

*Total industry output (Australian production) is more than Gross value of agricultural production in Australia (Table 7.2) as it also includes services to agriculture plus household own-account production of agricultural products.*
## A9. Biodiversity

### Table A9.1. List of threatened species in the Central Highlands study area classified under IUCN, EPBC, FFG and Victorian Advisory lists

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>IUCN Red List</th>
<th>EPBC category</th>
<th>FFG Act</th>
<th>Vic Advisory List</th>
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<tbody>
<tr>
<td><strong>Mammals</strong></td>
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<tr>
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<td>Bettongia gaimardi</td>
<td>Eastern Bettong</td>
<td>Near Threatened 2008; Lower Risk 1996</td>
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<tr>
<td>Dasyurus maculatus maculatus</td>
<td>Spotted-tailed Quoll</td>
<td>Near Threatened 2008; Vulnerable 1996</td>
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<td>Dasyurus viverrinus</td>
<td>Eastern Quoll</td>
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<td>Extinct on mainland. Not endangered in Tasmania</td>
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<tr>
<td>Isoodon obesulus obesulus</td>
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<td>Endangered 2001</td>
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<td>Near Threatened</td>
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<tr>
<td>Miniopterus schreibersii</td>
<td>Common Bent-wing Bat</td>
<td>Near Threatened 2008; Least Concern 2004; Lower Risk 1996</td>
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<td>Miniopterus schreibersii oceania</td>
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<td>Petaurus volans</td>
<td>Greater Glider</td>
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<td>Smoky Mouse</td>
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<td>Rhinolophus megaphyllus</td>
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<td>Smincthis annulata</td>
<td>White-footed Dunnart</td>
<td>Vulnerable 2008; Data Deficient 1996</td>
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### Reptiles

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<th>EPBC category</th>
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<th>Vic Advisory List</th>
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Vascular plants

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# A10. Ecosystem accounts

## Table A10.1 Ecosystem services – physical supply. Average values over 5-year time periods

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<th>2011-2015</th>
<th>2006-2010</th>
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<tr>
<td><strong>Area</strong></td>
<td>Ha</td>
<td>2,918</td>
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<tr>
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<td><strong>Water</strong></td>
<td>ML yr(^{-1})</td>
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<tr>
<td></td>
<td><strong>Timber - sawlogs</strong></td>
<td>m(^3) yr(^{-1})</td>
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<td><strong>pulplogs</strong></td>
<td>m(^3) yr(^{-1})</td>
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<td><strong>Water storage</strong></td>
<td>GL</td>
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<tr>
<td></td>
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<td>Mt yr(^{-1})</td>
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<td><strong>Carbon storage</strong></td>
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<th>Land cover</th>
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<td><strong>Area</strong></td>
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<td>m(^3) yr(^{-1})</td>
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<td><strong>Water storage</strong></td>
<td>GL</td>
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<tr>
<td></td>
<td><strong>Carbon sequestration</strong></td>
<td>Mt yr(^{-1})</td>
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<td><strong>Carbon storage</strong></td>
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### 2001-2005

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<th>built-up area</th>
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<th>crop/ pasture</th>
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<th>shrub / heath</th>
<th>riparian shrubs</th>
<th>woodland</th>
<th>montane woodland</th>
<th>open mixed forest</th>
<th>wet mixed forest</th>
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<th>mountain ash</th>
<th>rain-forest</th>
<th>total</th>
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<tr>
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<td></td>
<td>2,918</td>
<td>11,821</td>
<td>4</td>
<td>16,885</td>
<td>1,131</td>
<td>8,407</td>
<td>44,399</td>
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<td>11,010</td>
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<td>4,812</td>
<td>6,577</td>
<td>13,835</td>
<td>151,951</td>
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<td>64,476</td>
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#### Provisioning services

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<th>6,493</th>
<th>47</th>
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<th>12,635</th>
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<th>18,987</th>
<th>38,892</th>
<th>17,505</th>
<th>18,250</th>
<th>8,184</th>
<th>96,688</th>
<th>35,956</th>
<th>550,947</th>
<th>349,860</th>
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#### Regulating services

| Water storage GL | 960 |
| Carbon sequestration Mt yr⁻¹ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.43 | 0.18 | 0.26 | 0.01 | 1.05 |
| Carbon storage Mt | 0.00 | 0.00 | 0.00 | 0.25 | 0.01 | 0.03 | 0.18 | 0.03 | 0.63 | 3.85 | 0.13 | 0.19 | 0.96 | 2.07 | 9.18 | 25.29 | 38.36 | 52.12 | 1.81 | 135.09 |

### 1996-2000

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<th>bare open water</th>
<th>swamp</th>
<th>built-up area</th>
<th>crop</th>
<th>crop/ pasture</th>
<th>pasture grass</th>
<th>horticulture</th>
<th>pine plantation</th>
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<th>riparian shrubs</th>
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<th>alpine ash</th>
<th>mountain ash</th>
<th>rain-forest</th>
<th>total</th>
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<td>11,821</td>
<td>4</td>
<td>16,885</td>
<td>1,131</td>
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<td>44,399</td>
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<td>11,010</td>
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<td>213,081</td>
<td>64,476</td>
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#### Provisioning services

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<tr>
<td></td>
<td>pulplogs m³ yr⁻¹</td>
<td>66,600</td>
<td>97,684</td>
<td>153,122</td>
<td>641,297</td>
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#### Regulating services

| Water storage GL | 1,263 |
| Carbon sequestration Mt yr⁻¹ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.43 | 0.17 | 0.30 | 0.01 | 1.07 |
| Carbon storage Mt | 0.00 | 0.00 | 0.00 | 0.25 | 0.01 | 0.03 | 0.18 | 0.03 | 0.63 | 3.85 | 0.13 | 0.19 | 0.95 | 2.05 | 8.32 | 23.12 | 37.48 | 50.82 | 1.78 | 129.82 |
### 1991-1995

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<th>crop/pasture</th>
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### 1990

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<th>eucalypt plantation</th>
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<th>riparian shrubs</th>
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Further information:
http://www.nespthreatenedspecies.edu.au/