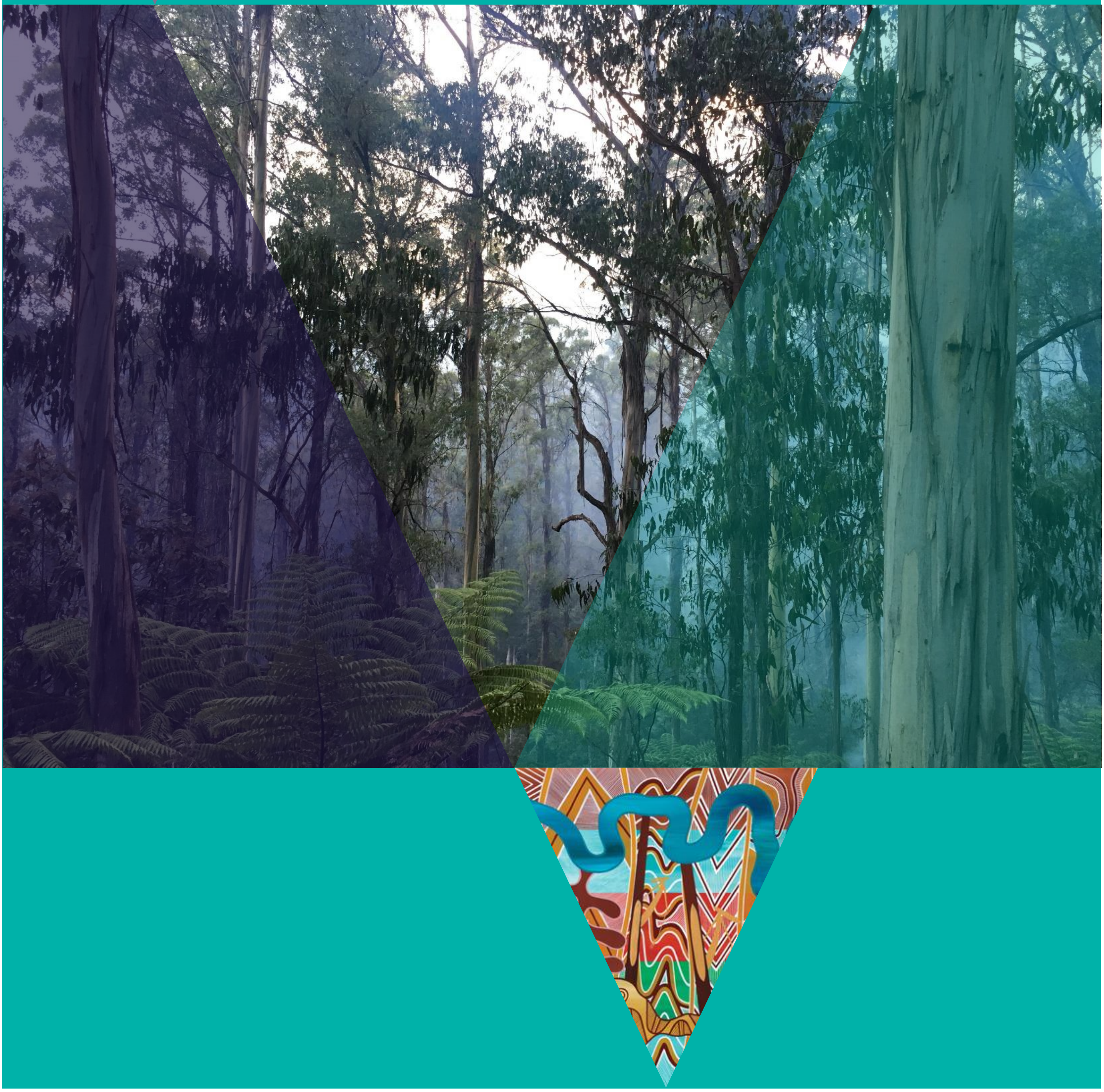
Ecosystem services from forests in Victoria

Assessment of Regional Forest Agreement regions



VICTORIA State Government
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Photo credit

Forest in the Upper Yarra Reservoir Park by Freya McCormick, 2019.

All data used in this document was collected prior to the 2019-20 bushfires in Victoria.

Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

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Executive summary

Victoria's forests have unique intrinsic value and they are also vital to our economy and society. Forest ecosystems contribute to the generation of goods and services upon which people depend. These contributions are known as ecosystem services and they range from the provision of clean water and timber, to the sequestration and storage of carbon, to providing opportunities for recreation and tourism. Although communities and industries benefit from ecosystem services, their value is either not captured in standard measures of economic activity such as gross state product or is not attributed to ecosystems.

This study addresses this information gap by providing an initial assessment of the types, quantity and value of ecosystem services provided by forests in Victorian Regional Forest Agreement (RFA) regions.

An ecosystem accounting framework consistent with the United Nations System of Environmental-Economic Accounting (SEEA) is used to assess the extent and condition of forest ecosystems across Victorian RFA regions, and to measure the ecosystem services these forests provide in physical and monetary terms.

Box 1 Victorian forest modernisation program

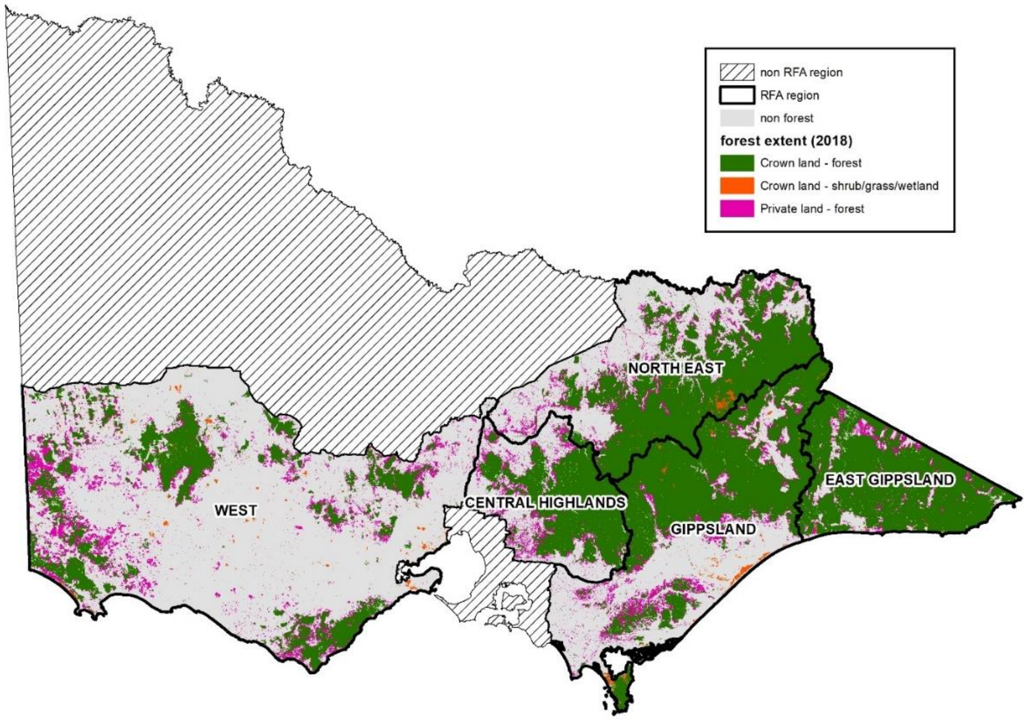
The Victorian Government has embarked on a major program to modernise the state's Regional Forest Agreements (RFAs) and the forest management system they accredit. Victoria has five RFAs negotiated with the Commonwealth Government.

This study supports the forest modernisation program by increasing our knowledge of the type, quantity and value of ecosystem services forests provide to the Victorian economy and society.

Forest ecosystem extent

Five RFAs cover over 13 million hectares of land, which is more than half of Victoria (Figure 1). They stretch from the southwest to the east of the state, covering all of Victoria except for the Wimmera-Mallee area in the northwest and the area east of Port Phillip Bay encompassing the Mornington Peninsula and Western Port Bay. There are over 6 million hectares of forest in the RFA regions, which is around 80 per cent of the state's forests. Most forests are on public land within state forests and parks (4.8 million hectares), with 1.2 million hectares on private land.

Figure 1 Forest ecosystem extent across Victorian RFA regions



Forest ecosystem services

Ecosystem services can flow directly to the community, such as when people visit a forest for recreation and relaxation, or when communities benefit from reduced climate change impacts as forests remove carbon dioxide from the atmosphere.

Ecosystem services also flow to industries that use them as inputs to the production of goods and services. Victorian industries that directly use forest ecosystem services include the tourism, timber, water, apiary and agriculture industries. Ecosystem services contribute to the value these industries add in the economy and the employment they provide.

Ecosystem services are typically classified as provisioning, regulating or cultural services. Key findings from this study are outlined below.

Provisioning services

In 2018, an estimated 6,432 gigalitres of water flowed from forests in RFA regions, which has an ecosystem service value of $0.8–1.3 billion.

Box 2 United Nations System of Environmental-Economic Accounting (SEEA)

The SEEA is a framework for capturing and organising information on the environment, including its contribution to economic and other human activity.

It is based on internationally agreed accounting concepts to gather and organise information in a consistent way that enables integration with socioeconomic information.

Countries around the world are implementing the SEEA to better understand, monitor and report on the linkages between the environment and the economy and society.

In 2018, around 9 million cubic metres of timber was harvested from plantation and native forests in RFA regions, which has an ecosystem service value of $82 million.

Forests also provide firewood directly to households. Around 45,000 cubic metres of firewood is collected from public land in RFA regions each year, which has an ecosystem service value of $3–7 million.

There are almost 2,500 beekeeping sites on public land across RFA regions. Between 1,000 and 1,500 tonnes per year of honey production is estimated to be dependent on forests, which has an ecosystem service value of $3–4.5 million.

Forests provide biomass for fodder which is grazed by livestock. Across RFA regions, almost 500,000 hectares of forest on public land is licensed for agricultural use.

Regulating services

Forests in RFA regions help regulate the flow of water, providing flood mitigation benefits to 646 localities across Victoria. This has a minimum estimated value of $97 million per year in avoided damages to property and infrastructure.

In 2018, forests in RFA regions prevented 382 million tonnes of soil erosion to major waterways. This has an estimated value of $3.1–8 billion based on the cost of artificially removing sediment from waterways.

Over 1,000 megatonnes of carbon is stored in public forests in RFA regions. In 2017, an estimated 41 megatonnes was sequestered by public forests in RFA regions, which has an ecosystem service value of $3 billion. In the same year carbon losses due to fire, harvesting and natural factors were estimated at 15 megatonnes, equating to a net increase in carbon stored of 26 megatonnes.

Forests in RFA regions are estimated to contribute around $1 million per year to commercial pollination services through apiarists accessing floral resources. More broadly, commercial and wild pollination services are a crucial input to agricultural production.

Other regulating services of air filtration and natural pest control are qualitatively discussed in this study.

Cultural services

Forests provide unique opportunities for recreation and tourism, with an estimated 34 million visits per year to forests (state forests and parks) in RFA regions. The estimated value of this ecosystem service is $905 million per year.

Several other cultural services and benefits provided by forests are qualitatively discussed in this study including: health and wellbeing, volunteering, amenity, cultural heritage connection and education and knowledge.

Variations across RFA regions

Many ecosystem services are quantified and valued for individual RFA regions, providing insights into the role of forests in different parts of Victoria in providing ecosystem services.

For example, forests in the Central Highlands RFA region provide significant water provision services to Melbourne's water supply system. Central Highlands forests also provide significant biomass for timber relative to other RFA regions.

Forests in the North East RFA region also provide significant water provision services, particularly to irrigation districts in northern Victoria, as well as significant erosion prevention services, partly due to the elevated terrain in this area.

Forests in the Gippsland and North East RFA regions sequester and store large volumes of carbon, as do forests in the Central Highlands RFA region on a per hectare basis.

There are large numbers of beekeeping sites on public land in the West and Gippsland RFA regions, indicating that forests in these regions may provide significant services to the apiary industry.

Conclusions and future directions

Understanding the linkages between ecosystems and the economy and society is integral to our knowledge of forests and to policy and management decisions.

The findings presented in this report provide an initial, indicative and conservative estimate of the quantity and value of ecosystem services provided by forests in Victorian RFA regions.

This study shows that forests provide a diverse range of ecosystem services that flow to Victorian communities and industries. It reveals the significant value forests contribute through these ecosystem services.

This is the first comprehensive study of forest ecosystem services across Victorian RFA regions. It establishes a framework that can be used to monitor trends in ecosystem extent and condition and flows of ecosystem services over time. It provides a reference point against which future ecosystem accounts can be compared.

Box 3 Sometimes valuation is difficult, but value is unquestionable

Measuring ecosystem services in both physical and monetary terms is challenging, and some ecosystem services are not quantified or valued in this study.

Other ecosystem services have only been partially valued, and estimates may understate the full value of ecosystem services.

Where ecosystem services have been quantified or valued, the confidence around these estimates varies due to a range of factors including the availability and quality of data and the robustness of methods that can be practically applied. These limitations are discussed throughout the report.

The monetary values of ecosystem services cannot necessarily be aggregated as some services may overlap.

Introduction

Forests have unique intrinsic value and they are also vital to our economy and society. Forest ecosystems contribute to the generation of goods and services upon which people depend. These contributions are known as ecosystem services and they range from the provision of clean water and timber, to the sequestration and storage of carbon, to providing opportunities for recreation and tourism. Although communities and industries benefit from ecosystem services, their value is either not captured in standard measures of economic activity such as gross state product or is not attributed to ecosystems.

This study addresses this information gap by assessing the types, quantity and value of ecosystem services provided by forests in Victorian Regional Forest Agreement (RFA) regions. It aims to enhance knowledge and understanding – both within government and the community – of the linkages between the environment and the economy and society, which can inform forest and land use policy and management.

This study uses the United Nations System of Environmental-Economic Accounting (SEEA), a relatively new and developing framework for capturing information that provides a clearer sense of the value to society of otherwise unrecognised or unobserved contributions from environmental assets. It is not the only way to appreciate such assets, but conveys an economic sense of what we may lose without effective future stewardship.

This report provides an overview of the study, outlining the general approach and key data and methods used. This is followed by presentation and discussion of findings: forest ecosystem accounts for Victorian RFA regions. The linkages between ecosystems and industries are also explored. The conclusion highlights key takeaways and future directions, while technical appendices include detailed discussion of the assessment of individual ecosystem services and the underpinning biophysical modelling and spatial data analysis.

Victorian forest modernisation program

The Victorian Government has embarked on a major program to modernise the state's Regional Forest Agreements (RFAs) and the forest management system they accredit. The program aims to improve the long-term management of Victoria's forests and ensure the RFAs reflect modern science and consider community needs. This study supports the modernisation program by increasing knowledge and understanding of the ecosystem services that flow from forests to the Victorian economy and society.

RFAs are agreements between the Commonwealth Government and states that establish the framework for the management of forests in an RFA region. They are an outcome of the 1992 National Forest Policy Statement through which governments committed to the sustainable management of all Australian forests, whether the forest is on public or private land, reserved for conservation or available for timber production.

Victoria has five RFAs covering over 13 million hectares of land and over 6 million hectares of forest. They stretch from the southwest to the east of the state, covering all of Victoria expect for the Wimmera-Mallee area in the northwest and the area east of Port Phillip Bay encompassing the Mornington Peninsula and Western Port Bay.

More information is available at www.forestsandreserves.vic.gov.au/

Overview of study

This study uses an ecosystem accounting framework consistent with the United Nations System of Environmental-Economic Accounting (SEEA) to identify, quantify and value ecosystem services provided by forests in Victorian RFA regions.

The key outputs are forest ecosystem extent accounts and physical and monetary ecosystem service flow accounts for Victorian RFA regions. An example forest ecosystem condition account has also been produced, although the relationship between ecosystem condition and flows of ecosystem services is not established. Spatial maps of ecosystem extent and ecosystem services complement the accounts.

Accounts are produced for a notional reference year of 2018, as this represents the best year that data is available to measure ecosystem extent and ecosystem services. While timeseries data are available for some ecosystem services, for others data are available for one year only. An ecosystem extent account is also produced for 2013.

The ecosystem service flow accounts presented in this study show the *supply* of ecosystem services by forests in different RFA regions. While accounts showing the *use* of ecosystem services by different economic units (households, industries and government) have not been produced, the users of each ecosystem service are clearly identified and described, including industries that use forest ecosystem services as inputs to the production of goods and services in the economy.

Accounts and spatial maps have been produced by drawing on a range of environmental and socioeconomic data, with EnSym and ArcGIS software used for environmental modelling and spatial analysis. Localised environmental and socioeconomic data has been used where possible, to support meaningful estimates that reflect variation in ecosystems and ecosystem services across RFA regions.

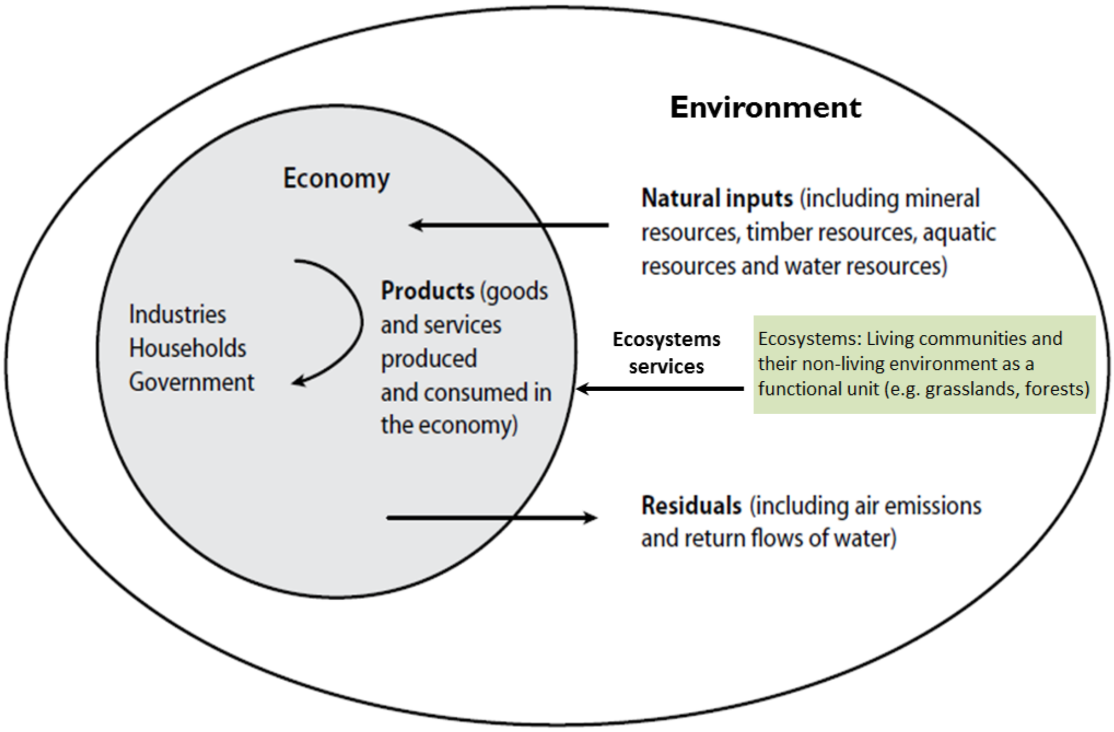
This section of the report provides an overview of the environmental-economic accounting framework. Key data used in this study are outlined, as well as the approach to biophysical modelling and spatial analysis. An overview of methods used to value ecosystem services is also provided. Study findings are presented and discussed in the next section of the report.

Environmental-economic accounting

An ecosystem accounting framework consistent with the SEEA is used to assess the extent and condition of forest ecosystems across Victorian RFA regions, and the flows of ecosystem services generated by these forest ecosystems.

The SEEA is a multipurpose conceptual framework for describing the interactions between the environment and the economy and society. It builds on the concepts and principles of the System of National Accounts which is used to measure gross domestic product and other economic and social indicators. The SEEA framework, including the ecosystem accounting component, is illustrated in Figure 2.

Figure 2 Overview of the System of Environmental-Economic Accounting



Source: Adapted by DELWP from the United Nations 2014

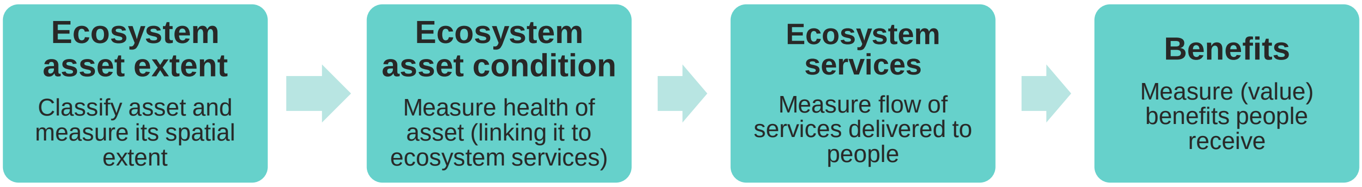
Ecosystem accounting links ecosystems to economic and other human activities through a series of conceptual relationships and accounting tables. As a function of their extent and condition, ecosystems generate flows of ecosystem services which contribute to benefits that people receive. This conceptual model is illustrated in
Figure 3.

The ecosystem accounting component of the SEEA is an experimental framework that was released in 2014 (known as SEEA Experimental Ecosystem Accounting), which jurisdictions around the world – including Victoria[1] – have been piloting. In 2017, the United Nations commenced a revision process with the intention to reach agreement on issues and formalise the framework by 2020. This study has been undertaken while the revision is underway, and consequently the application of concepts may differ from the framework that is formalised.

1. See Department of Sustainability and Environment 2013, *Victorian experimental ecosystem accounts*, State of Victoria, Melbourne; Department of Environment, Land, Water and Planning & Parks Victoria 2015, *Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne; and Department of Environment, Land, Water and Planning 2016, *Marine and coastal ecosystem accounting: Port Phillip Bay*, State of Victoria, Melbourne.

   More information on environmental-economic accounting at the Department of Environment, Land. Water and Planning (DELWP) is available at: www.environment.vic.gov.au/accounting-for-the-environment

Figure 3 Ecosystem accounting framework



Box 4 Environmental-economic accounting in Australia

Environmental-economic accounting, including experimental ecosystem accounting, is being implemented by government agencies, academic institutions and organisations around Australia.

At a national level, Australia's commitment to implementing the SEEA is set out in a strategy and action plan endorsed by Commonwealth, state and territory environment ministers.[2] Findings and lessons from this study of forests in Victoria will be shared to inform the development and implementation of the national approach.

At a state level, this study contributes to the Department of Environment, Land, Water and Planning's (DELWP) strategy *Valuing and accounting for Victoria's environment*, which outlines a plan for adopting the SEEA to improve reporting, decision-making and evaluation at DELWP.[3] It aligns with broader efforts to embed environmental-economic accounting concepts in Victoria, such as the state of the environment reporting undertaken by the Commissioner for Environmental Sustainability.[4]

Environmental-economic accounting is also being undertaken within academic institutions, notably by the Australian National University's Fenner School of Environment and Society which published ecosystem accounts for the Central Highlands region of Victoria in 2017.[5]

Organisations are increasingly integrating natural capital information with traditional businesses reporting to better understand their impact on – and reliance on – the environment. In 2018, Forico and the Institute for the Development of Environmental-Economic Accounting (IDEEA) published an environmental-economic accounting study of Forico's Surry Hills Estate in northern Tasmania.[6]

Ecosystem extent and condition

Ecosystem assets are characterised at a point in time using two key metrics: extent and condition. Extent is a spatial measure (such as hectares), while condition describes the quality of ecosystem assets. Condition is important because it underpins an asset's capacity to fully function and provide ecosystem services. An ecosystem that is in good condition will typically generate more services than

2. Department of Environment and Energy 2018, *Environmental economic accounting: A common national approach strategy and action plan*, Commonwealth of Australia, Canberra.
3. Department of Environment, Land, Water and Planning 2015, *Valuing and accounting for Victoria's environment: Strategic plan 2015–2020*, State of Victoria, Melbourne.
4. Commissioner for Environmental Sustainability Victoria 2015, *Framework for the Victorian 2018 state of the environment report: State and benefit*, State of Victoria, Melbourne.
5. Keith, H, Vardon, M, Stein, J, Stein J & Lindenmayer, D 2017a, *Experimental ecosystem accounts for the Central Highlands of Victoria: Final report*, Australian National University Fenner School of Environment and Society, Canberra; Keith, H, Vardon, M, Stein, J, Stein J & Lindenmayer, D 2017b, *Experimental ecosystem accounts for the Central Highlands of Victoria: Appendices*, Australian National University Fenner School of Environment and Society, Canberra.
6. Forico & IDEEA Group 2018, *Making every hectare count: Environmental-economic accounting for Forico's Surry Hills Estate, Tasmania*.

one in poor condition, if all other variables remain the same. A change in the condition metric must reflect a change in the health of the asset and its ability to function and provide ecosystem services.

In an accounting framework, changes in condition encompass both natural changes and changes induced by economic and other human activity. For instance, if there is an extended wet or dry period this may have an impact on the condition of an asset and its ability to function. Alternatively, an economic activity may be undertaken (such as harvesting or tourism) that results in a change in condition. It is important to understand the drivers of changes in condition in order to formulate policy or management responses.

Ecosystem services and benefits

Ecosystem services provide the link between ecosystem assets and the benefits derived and enjoyed by people. They are generated through ecosystem processes reflecting the combination of asset characteristics, intra-ecosystem and inter-ecosystem flows.[7] The generation of ecosystem services can be described as a natural production process, and they must have a clearly identified 'user' or 'beneficiary'. In an accounting framework, supply of ecosystem services from the environment must match the quantity used by people. Users of ecosystem services are economic units such as households, industries or government.

The Common International Classification of Ecosystem Services (CICES) is designed to integrate with the SEEA and aims to provide a clear and consistent classification of ecosystem services for accounting purposes.[8] This study draws on CICES – as well as other forest ecosystem accounting studies (see Box 5) – to identify and define ecosystem services generated by forests in Victoria.

Ecosystem services are typically categorised as provisioning, regulating or cultural services – as shown in Table 1. Ecosystem services can also be classed as intermediate or final, and several intermediate ecosystem services may contribute to the provision of a final ecosystem service. For example, if water in a river is extracted for drinking, then it could be regarded as a final service. However, the provision of water could be considered an intermediate service for the final service of provision of fish. When assessing ecosystem services, care must be taken to ensure that final ecosystem services and their contribution to benefits are identified and valued. Whether a particular ecosystem service is regarded as final or not can vary depending on the context and boundary of the study.[9]

Non-living ecosystem outputs that contribute to human wellbeing – such as minerals – are known as abiotic services. Information on abiotic services is often presented alongside ecosystem services. This is useful because ecosystem accounting can be used to organise information for assessing alternative uses of land, and often there are trade-offs between combinations of ecosystem and abiotic services that stem from different uses of land.

7. United Nations 2014, *System of environmental-economic accounting 2012: Central framework,* United Nations, New York, p. 14.
8. European Environment Agency 2019, 'CICES: Towards a common classification of ecosystem services', version 5.1, access October 2019 at https://cices.eu/
9. Haines-Young, R & Potschin, M 2018, *Common International Classification of Ecosystem Services (CICES) V5.1: Guidance on the application of the revised structure*, Fabis Consulting, Nottingham, p. 4.

Table 1 Types of ecosystem services

Category	Definition	Examples
Provisioning services	Material ecosystem outputs that provide benefits to people from the consumption of tangible goods and services.	Provision of food, water and other raw materials.
Regulating services	Ecosystem functions that provide benefits to people from regulating climate, hydrologic, biogeochemical and other cycles	Water and air filtration, soil retention, water flow regulation, carbon sequestration and storage, and biological processes such as pest control, pollination and genetic diversity.
Cultural services	Non-material ecosystem outputs that provide cultural, social, intellectual or health benefits to people.	Opportunities for recreation and relaxation, cultural and community connection, and knowledge development.

Linkages between ecosystems and industries

Like the community, industries rely on the ecosystem services generated by ecosystem assets. For many industries the linkages are complex and indirect. For example, the accommodation and food services industry uses water as an input to production, which is supplied by the water industry which is a direct user of the ecosystem service of water provision; or the tourism industry may benefit from a longer snow season due to the sequestration and storage of carbon by forests contributing to climate change mitigation. However, some industries directly use ecosystem services as inputs to production, such as the timber industry which harvests biomass from forests.

Ecosystem services are combined with other inputs such as labour and capital to produce goods and services which add value in the economy and benefit people. Industries also provide socioeconomic benefits such as employment. Understanding the linkages between ecosystems and industries enhances knowledge of the reliance of industries on ecosystems, and the contribution ecosystems make to industries.

Box 5 Forest ecosystem accounting in Victoria and other jurisdictions

Forest ecosystem accounting has been undertaken in several jurisdictions, including Victoria. In undertaking this study relevant studies were reviewed and have informed the methods and information used in this assessment.

Experimental ecosystem accounts for the Central Highlands of Victoria

In 2017, academics from the Australian National University published experimental ecosystem accounts for the Central Highlands of Victoria.[10] The study area overlaps with the Central Highlands RFA region. The experimental accounts assessed ecosystem extent and condition as well as water provision, timber provision, agriculture and tourism. The study also considered the value added in the economy by industries that use ecosystem services from the Central Highlands.

Valuing Victoria's parks

In 2015, DELWP and Parks Victoria undertook a study of ecosystem services and benefits provided by Victorian parks in metropolitan and regional areas, including parks that encompass forest ecosystems.[11] The study assessed a range of ecosystem services and benefits including water provision, honey, water purification, flood and stormwater protection, carbon storage, coastal protection, pollination and recreation and health.

Developing UK natural capital accounts: Woodland ecosystem accounts

In 2015, the Department for Environment, Food and Rural Affairs (Defra) published ecosystem accounts for woodlands in the United Kingdom.[12] This included a physical stock account of woodland extent and condition, as well as physical and monetary ecosystem service flow accounts that include biomass for timber, carbon sequestration and recreation.

The SEEA EEA biophysical ecosystem service supply-use account for the Netherlands

In 2018, Statistics Netherlands published physical ecosystem service supply and use accounts for the Netherlands.[13] The accounts link to ecosystem asset extent accounts and cover all ecosystem types in the Netherlands, including forests. Ecosystem services generated by forests that are measured in biophysical terms are: water, timber, carbon sequestration, erosion control, air filtration, protection against heavy rainfall, pollination, pest control, and recreation and tourism. Physical supply and use accounts have been produced for 2006 and 2013. Monetary supply and use accounts are currently being developed.

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10. Keith, H, Vardon, M, Stein, J, Stein J & Lindenmayer, D 2017a, *Experimental ecosystem accounts for the Central Highlands of Victoria: Final report*, Australian National University Fenner School of Environment and Society, Canberra; Keith, H, Vardon, M, Stein, J, Stein J & Lindenmayer, D 2017b, *Experimental ecosystem accounts for the Central Highlands of Victoria: Appendices*, Australian National University Fenner School of Environment and Society, Canberra.
11. Department of Environment, Land, Water and Planning & Parks Victoria 2015, *Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne
12. Eftec 2015, *Developing UK natural capital accounts: Woodland ecosystem accounts*, report prepared for the Department for Environment, Food and Rural Affairs, London.
13. Remme, R, Lof, M, de Jongh, L, Hein, L, Schenau, S, de Jong, R & Bogaart, P 2018, *The SEEA EEA biophysical ecosystem service supply-use account for the Netherlands*, Statistics Netherlands.

Biophysical modelling and spatial data analysis

Ecosystem accounts and spatial maps have been produced by drawing on a range of environmental and socioeconomic data, with localised data used where possible to support meaningful estimates that reflect variation in ecosystems and ecosystem services across RFA regions. A combination of 'bottom up' and 'top down' approaches have been used in the assessment.

A bottom up approach was used to assess ecosystem extent, condition and several ecosystem services. Bottom up assessments draw on biophysical modelling using EnSym or spatial data analysis using ArcGIS. Biophysical modelling of water yield and soil erosion informed the assessment of three ecosystem services: water provision, water flow regulation and soil retention. Analysis of existing spatial datasets underpins the assessment of ecosystem extent, condition and several ecosystem services including: provision of fodder, plantation extent, carbon sequestration and storage, and habitat for species, as well as the abiotic service of mineral resources. Spatial modelling of apiary sites informed the disaggregation of statewide data for honey and pollination.

A top down approach was used to assess ecosystem services where spatial data were not available, such as honey, pollination and recreation and tourism. However, the disaggregation of data was informed by spatial analysis of ecosystem extent.

Box 6 EnSym

The Environmental Systems Modelling Platform (EnSym) is a computer software package originally designed to quantify the environmental benefits of on-ground conservation and revegetation works.

Environmental impacts reported by EnSym cover water quantity and quality, plant physiology, native vegetation and groundwater.

EnSym can be used to assess the environmental impacts of land use changes and to produce information and accounts that align with the United Nations System of Environmental-Economic Accounting (SEEA).

More information is available at ensym.biodiversity.vic.gov.au

Core spatial and temporal datasets used in this study were obtained from the Victorian Forest Monitoring Program (see Box 7), the Victorian Spatial Data Library[14], Victorian Water Register[15], Scientific Information for Land Owners (SILO)[16] and the CSIRO Soil and Landscape Grid of Australia[17]. These datasets include information on forest extent, forest condition, land tenure/use/cover, forest type, climate, administration zones, hydrology, topography and biomass. While spatial datasets underpin the assessment of ecosystem extent, condition and ecosystem services, this has been supplemented with non-spatial data and information to fully quantify and value flows of ecosystem services.

The analysis and modelling undertaken for individual ecosystem services is discussed in more detail in Appendix A. Appendix D provides a complete list of all input datasets used and datasets generated, as well as further information on biophysical modelling and spatial data analysis.

14. See https://www2.delwp.vic.gov.au/maps/spatial-data/victorian-spatial-data
15. See https://waterregister.vic.gov.au/
16. See https://www.longpaddock.qld.gov.au/silo/
17. See https://www.clw.csiro.au/aclep/soilandlandscapegrid/

Box 7 Victorian Forest Monitoring Program

The Victorian Forest Monitoring Program (VFMP) is a statewide forest information system that has been developed to assess and monitor the extent and condition of Victorian forests. It provides baseline data for long term trend detection and prediction of type and severity of future changes.

The VFMP uses a network of permanent ground plots located across Victoria's public forests and parks, together with aerial photography and satellite imagery. Together these provide information on attributes (such as forest structure, species diversity, canopy condition and soil characteristics) that can be used to derive indicators and measure changes in the extent and condition of forests

The VFMP is Australia's most comprehensive forest monitoring program and provides a platform to meet statutory reporting obligations and support forest policy and management decisions.

More information can be found at www.forestsandreserves.vic.gov.au

Valuation of ecosystem services

In addition to measuring flows of ecosystem services in physical quantities (such as weight or volume), this study aims to estimate their value in monetary terms. In principle, other units can also be used to represent value, but money is generally preferred because it is a familiar, comparable and continuous unit of measurement.[18]

Valuation of ecosystem services focuses on the actual use of ecosystem services by people and industries, rather than the capacity of ecosystems to generate services. Exchange values for these 'transactions' or use of ecosystem services by people are estimated, even if market transactions do not occur. This is consistent with ecosystem accounting principles.

Ecosystem services can be challenging to value because they are often not traded in markets, meaning that prices are not readily observable. However, a range of techniques can be used to estimate value, some of which are described in Table 2.

There are two groups of valuation techniques: revealed preference and stated preference. Revealed preference techniques rely on prices, data and information about choices and behaviours in existing or related markets for ecosystem services. Stated preference techniques rely on surveys and experiments where people make statements or choices in hypothetical markets for ecosystem services. There are strengths and weaknesses to each approach. Where available, revealed preference data is preferred, with due recognition that price may not equal value when markets are imperfect. Suitable revealed preference data is used throughout this study.

Using context specific data is generally preferred. However, primary data collection is often time consuming and resource intensive. Moreover, it can be possible to apply valuation evidence from elsewhere to a study context with appropriate adjustments. The process of applying existing valuation evidence to a study is called value transfer. Value transfer is often used because it provides an adequate approximation of value and is achievable given the resources and time available for a study.

This study predominantly uses Victoria-specific valuation evidence in assessing ecosystem services. However, in most cases data has been sourced and adjusted from existing Victorian and Australian

18. Ozdemiroglu, E & Hails, R (eds) 2016, *Demystifying economic valuation*, Valuing nature paper VNP04.

studies to match the purpose and boundaries of this study. Valuation methods used for individual ecosystem services are discussed in detail in Appendix A.

Table 2 Valuation techniques

Technique	Examples
Revealed preference Estimates values based on observed behaviours and actual choices in existing or related markets for ecosystem services	**Market price:** Derives values from observed market prices for goods provided directly by the ecosystem, such as fish or timber. **Productivity method:** Where an ecosystem service affects production levels, costs or prices of market goods or services, the contribution to output is used as a proxy for the value. **Replacement cost:** Estimates value based on the cost of providing the service (if there is willingness to pay) through alternative means, such as filtering water in a water purification plant instead of a wetland. **Hedonic pricing:** Derives values for amenity and the aesthetic qualities of the environment by observing how a related market changes in value due to proximity, such as house prices changing with proximity to the coast. **Travel cost method:** Generally used to estimate the recreational values of particular sites by observing visitor travel patterns and the expenditure that people are willing to pay in order to enjoy such a site.
Stated preference Estimates values based on statements or choices in hypothetical markets for ecosystem services	Stated preference surveys can be used to present hypothetical but budget constrained choices to people about how much they are willing to pay for varying flows of ecosystem services. A group of people is sampled, and the data analysed to estimate economic value. The quality of results is highly dependent on the rigour of survey design and implementation. Two main techniques are used: **Contingent valuation:** Asks respondents direct questions about the costs they are willing to pay (or willing to accept). **Choice modelling:** Asks respondents to make choices between options that involve different costs.

Forest ecosystem accounts for Victorian RFA regions

Forest ecosystem extent

Asset extent – Classify asset and measure its extent → **Asset condition** – Measure health of asset → **Ecosystem services** – Measure flow of services to people → **Benefits** – Measure (value) benefits people receive

Victoria's five regional forest agreements (RFAs) cover over 13 million hectares of land, which is over half of the state. RFAs cover all of Victoria except for the northwest Wimmera-Mallee area and the area to the east of Port Phillip Bay encompassing the Mornington Peninsula and Western Port Bay (see Figure 4).

In 2018, there were 6.2 million hectares of forest within Victorian RFA regions, which is around 80 per cent of the state's forests. Most of this forest (4.8 million hectares) is within state forests and parks, with 1.2 million hectares on private land. The remaining forest (0.2 million hectares) is on other types of public land, such as Commonwealth land or plantation tenured public land.

The size of each RFA region varies, as does the proportion of each region that is forest. For example, the West RFA region is the largest (over 5.7 million hectares) and is around 25 per cent forest, whereas the East Gippsland RFA region is the second smallest (1.2 million hectares) and is over 90 per cent forest.

Figure 4 Forest extent across Victorian RFA regions (2018)

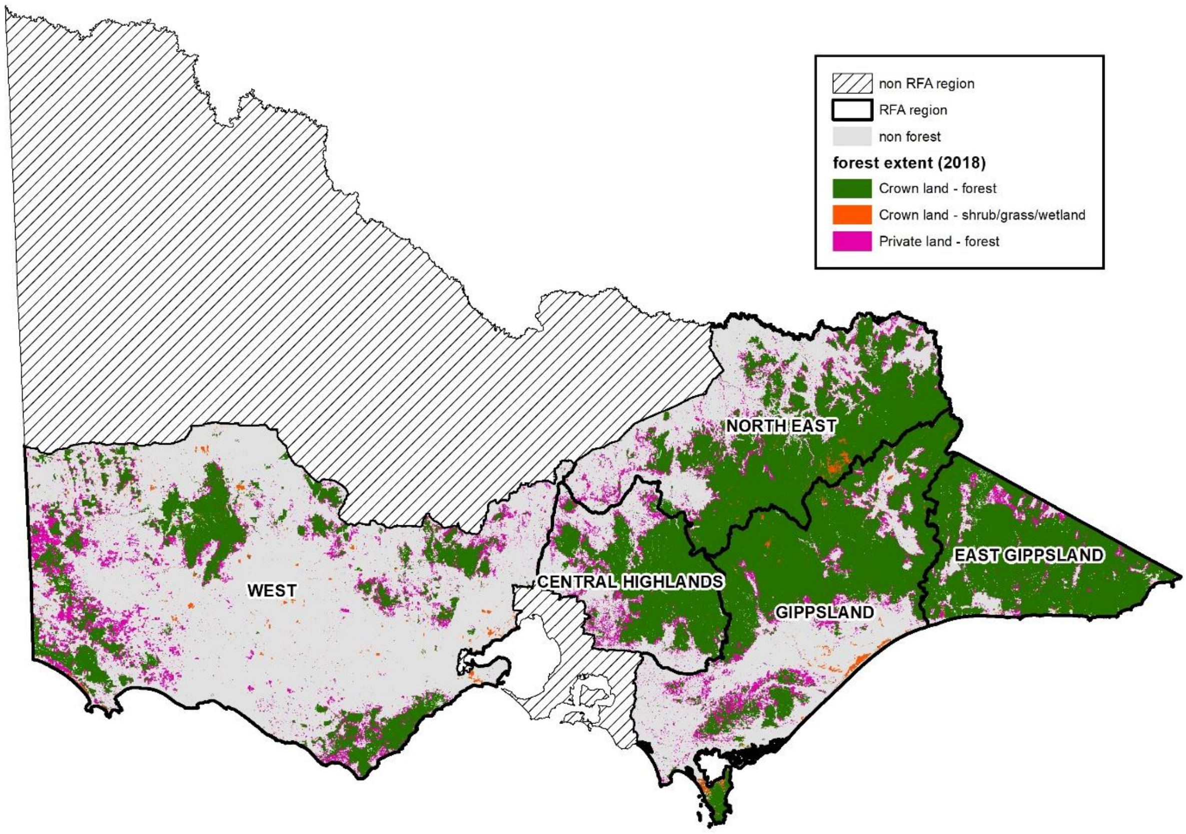


Table 3 shows the extent of forest within each RFA region in 2018, including by land tenure type. Around 80 per cent of forest in RFA regions is on public land, with the vast majority of this in state forests (45 per cent of total forest) and parks (32 per cent of total forest).

However, the mix of forest on public and private land varies between RFA regions. The West RFA region has the highest proportion of forest on private land (39 per cent of all forest in the region), which partly reflects the significant plantation industry in the west of the state. All other RFA regions have less than 20 per cent of forest on private land, and the East Gippsland RFA region has the lowest proportion on private land (7 per cent of all forest in the region).

Table 3 Forest ecosystem extent (hectares, 2018)

	Forest on public land				Forest on private land	Total forest	Non-forest	Total
	State forest	Park	Plantation	Other				
Central Highlands	385,401	185,453	17,151	6,742	141,121	735,868	395,949	1,131,817
East Gippsland	575,717	452,245	5,364	-	77,286	1,110,612	101,815	1,212,427
Gippsland	799,937	498,177	16,361	47,235	259,077	1,620,787	1,005,739	2,626,526
North East	715,426	383,561	13,922	45,121	173,536	1,331,566	985,269	2,316,835
West	293,802	474,196	34,331	37,363	529,854	1,369,546	4,401,203	5,770,749
Total	2,770,283	1,993,632	87,129	136,461	1,180,874	6,168,379	6,889,975	13,058,354

In this study, forest extent is defined and measured using a forest cover dataset developed through the Victorian Forest Monitoring Program (VFMP). The VFMP, in line with the National Forest Inventory[19], defines forest as: "*An area, incorporating all living and non-living components, that is dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding two metres and with existing or potential crown cover of overstorey strata about equal to or greater than 20 per cent. This includes Australia's diverse native forests and plantations, regardless of age. It is also sufficiently broad to encompass areas of trees that are sometimes described as woodlands*"[20]. The VFMP dataset includes forest on all land tenure types. Forest extent is intersected with a land tenure spatial layer to determine the extent of forest on different types of land.

The forest ecosystem condition account and ecosystem service flow accounts build upon this forest extent mapping, either through bottom-up biophysical modelling and spatial analysis or top-down disaggregation of data. The exception is the assessment of provision of habitat for species, which uses a different extent dataset. This variation is discussed in the technical appendices.

Figure 5 and Table 4 show change in forest ecosystem extent between 2013 and 2018. Forest extent increased by around 1 per cent across the five RFA regions. Net increases in the East Gippsland, Gippsland and West RFA regions (around 75,000 hectares) were partially offset by net decreases in the Central Highlands and the North East (around 6,000 hectares). The net change in forest extent was less than 1 per cent for the Central Highlands, East Gippsland and the North East RFA regions. There was a net increase of 2 per cent in Gippsland and 2.7 per cent in the West, which is mostly driven by growth in plantations.

The impact of large fires can be seen in Figure 5 as reductions in forest ecosystem extent. Significant fires between 2013 and 2018 within the RFA regions include the Grampians (2013) in western Victoria, and Aberfeldy (2013), Harrietville (2013) and Dargo (2014) in eastern Victoria. Timber harvesting (both native and plantation) is another driver of change in forest ecosystem extent.

19. See http://www.agriculture.gov.au/abares/forestsaustralia/australias-national-forest-inventory
20. See https://data.gov.au/data/dataset/forests-of-australia-2018

Figure 5 Change in forest ecosystem extent between 2013 and 2018

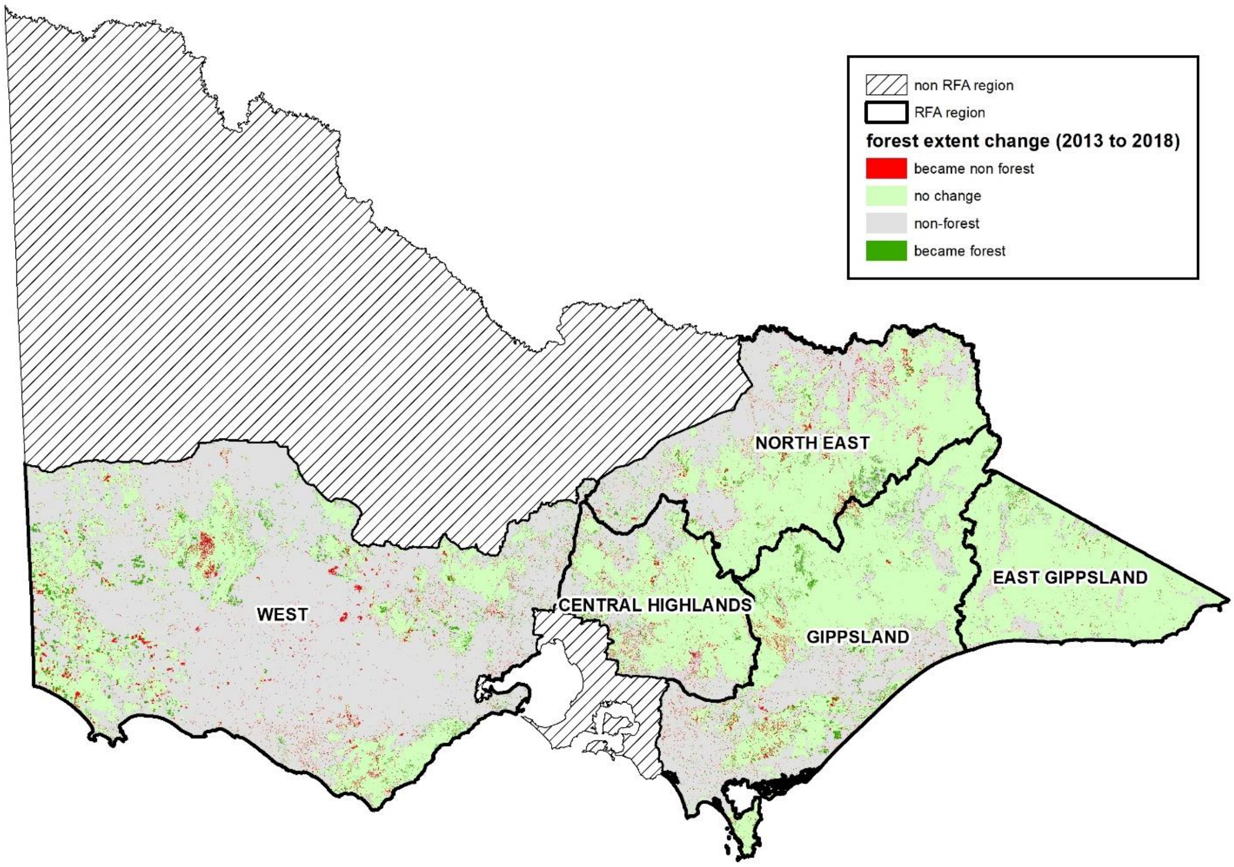
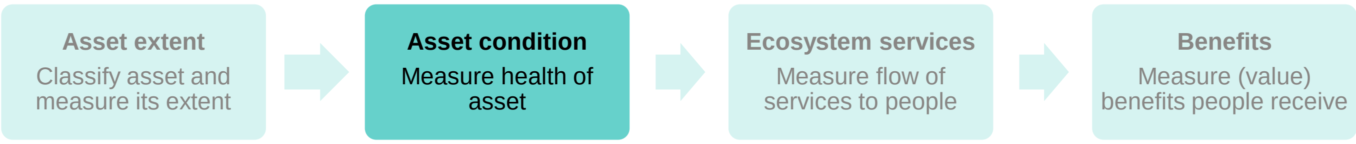


Table 4 Change in forest ecosystem extent between 2013 and 2018 (hectares)

	RFA region					Total
	Central Highlands	East Gippsland	Gippsland	North East	West	
Opening stock (2013)						
Forest	739,260	1,103,595	1,589,269	1,334,077	1,333,630	6,099,831
Non-forest	392,557	108,832	1,037,257	982,758	4,437,119	6,958,523
Total	1,131,817	1,212,427	2,626,526	2,316,835	5,770,749	13,058,354
Net additions to stock						
Forest		7,017	31,518		35,916	74,451
Non-forest	3,392			2,511		5,903
Total	3,392	7,017	31,518	2,511	35,916	80,354
Net reductions to stock						
Forest	3,392			2,511		5,903
Non-forest		7,017	31,518		35,916	74,451
Total	3,392	7,017	31,518	2,511	35,916	80,354
Closing stock (2018)						
Forest	735,868	1,110,612	1,620,787	1,331,566	1,369,546	6,168,379
Non-forest	395,949	101,815	1,005,739	985,269	4,401,203	6,889,975
Total	1,131,817	1,212,427	2,626,526	2,316,835	5,770,749	13,058,354

Forest ecosystem condition



Ecosystem condition accounts require data on the health of ecosystem assets. This can be a single metric, multiple separate metrics, or a composite of several metrics to create a condition score. In this section, native vegetation condition mapping undertaken by Arthur Rylah Institute is reported to demonstrate how ecosystem condition accounts can be compiled and presented.[21] This is just one example of how condition information can be presented in an ecosystem accounting framework. For example, experimental woodland ecosystem accounts published by Defra in the United Kingdom reported several condition metrics including species type and age, biomass and carbon stock.[22]

The Victorian dataset is based on condition mapping from 2007, updated to current ecosystem extent. For this reason, it should be interpreted as a high-level indicator of condition only. While temporal data is not available, it is reasonable to assume that there would be change over time. Ecosystem condition can be influenced by a wide range of human and non-human pressures and activity such as bushfires, climate change, pest species, harvesting and tourism.

Table 5 presents an example condition account for forest ecosystems across Victorian RFA regions, with a score of 1 representing high condition and 0 representing low condition. Average condition score per hectare of forest is reported for different tenure types, as well as for the whole of each RFA region.

Forest assets in state forests and national parks have high condition scores across all RFA regions (ranging from 0.80 to 0.84). The average condition of forest on other public land (which includes Commonwealth land) is more variable, ranging from 0.53 in the North East and West RFA regions to 0.75 in East Gippsland. Average condition of forest on plantation tenured public land is highly variable, ranging from just 0.17 in the West to 0.70 in the Central Highlands. Average condition of forest on private land also varies, ranging from 0.35 in the Central Highlands to 0.74 in East Gippsland.

Ideally, temporal information on forest ecosystem condition could be used to monitor change in ecosystem extent and condition alongside changes in the flows of ecosystem services. This is a key objective of ecosystem accounting and a potential area for future work in the context of Victorian forests: understanding how changes in extent and condition impact on the capacity of forest ecosystems to generate flows of ecosystem services that contribute to benefits in the economy and community.

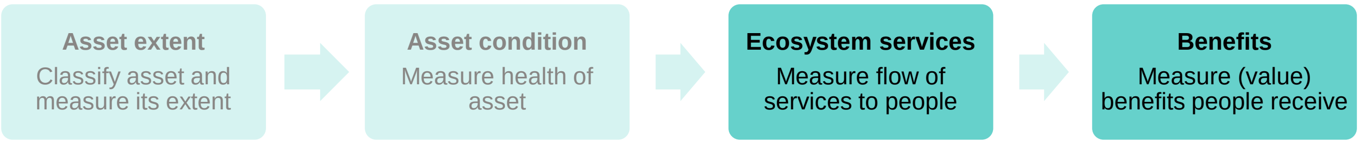
21. See Newell, G, White, M, Griffioen, P, Conroy, M 2006, 'Vegetation condition mapping at a landscape-scale across Victoria', *Ecological management & restoration*, volume 7, issue s1, pp. 65-68.

22. Eftec 2015, *Developing UK natural capital accounts: Woodland ecosystem accounts*, report prepared for the Department for Environment, Food and Rural Affairs, London, p. 29.

Table 5 Forest ecosystem condition (average score per hectare of forest)

	Forest on public land				Forest on private land	Weighted average
	State forest	Parks	Plantation	Other		
Central Highlands	0.81	0.81	0.70	0.68	0.35	0.79
East Gippsland	0.84	0.82	n.a.	0.75	0.74	0.82
Gippsland	0.83	0.81	0.53	0.65	0.57	0.78
North East	0.83	0.83	0.22	0.53	0.72	0.79
West	0.81	0.80	0.17	0.53	0.44	0.65

Forest ecosystem services



Forests in Victorian RFA regions provide a diverse range of ecosystem services. These ecosystem services flow to people and industries, and contribute to benefits in the community and the economy. Ecosystem services provided by forests in Victorian RFA regions are outlined in Table 6 and discussed throughout this section. Appendix C relates each ecosystem service to the Common International Classification of Ecosystem Services (CICES).

Table 6 Ecosystem services provided by forests in Victorian RFA regions

Provisioning	Regulating	Cultural
Water provision	Water flow regulation	Recreation and tourism
Biomass for timber	Soil retention	Social and community connection
Biomass for firewood	Carbon sequestration and storage	Cultural heritage connection
Honey	Pollination	Amenity
Fodder	Habitat for species	Education and knowledge
	Air filtration	
	Pest and disease control	

Ecosystem service flow accounts

Table 7 and Table 8 present physical and monetary ecosystem service flow accounts for forests in RFA regions. Physical and monetary estimates are for 2018 unless otherwise stated, as this represents the best year that data is available across ecosystem services.

Flows of some ecosystem services are reported by RFA region, where this could be done through bottom-up analysis or where top-down data could be disaggregated with enough confidence. Flows of other ecosystem services are reported only for the RFA regions as a whole.

An indication of confidence in the quantification or valuation of ecosystem services is provided in the far right column of each table, with green representing higher confidence in the assessment of quantity or value, orange representing medium confidence and red representing lower confidence.

For some ecosystem services the actual physical flow could not be estimated, and proxy indicators are reported instead. An example of this is provision of fodder, where area of agricultural licenses is reported instead of the actual quantity of fodder.

Not all ecosystem services could be measured in physical or monetary terms, but this does not imply a lack of value. While some ecosystem services are not included in these tables, they are qualitatively discussed in this report.

The remainder of this section summarises key findings on ecosystem services provided by forests in Victorian RFA regions. Detailed discussion of findings and methods used to quantify and value ecosystem services is provided in Appendix A.

Table 7 Physical flow of ecosystem services from forests in RFA regions (2018 estimate unless otherwise stated)

	Central Highlands	East Gippsland	Gippsland	North East	West	Total	Confidence
Ecosystem services							
Provisioning services							
Water (GL)	1,748	145	1,116	2,414	1,010	6,432	
Native timber (m^3)	867,488	141,163	112,700	33,114	-	1,154,465	
Plantation timber[a] (m^3)	n.a.	n.a.	n.a.	n.a.	n.a.	7,839,128	
Firewood[b] (m^3)	n.a.	n.a.	n.a.	n.a.	n.a.	45,000	
Honey (tonnes)	n.a.	n.a.	n.a.	n.a.	n.a.	1,000-1,500	
Fodder[c] (ha agricultural licenses)	5,783	44,354	301,147	132,126	10,980	494,391	
Regulating services							
Water flow regulation[c] (number of localities with reduced flood peaks)	142	57	195	183	347	646[d]	
Soil retention (million tonnes)	58	83	79	135	27	382	
Carbon sequestration[a] (MtC)	5	5	14	10	7	41	
Carbon storage[a] (MtC)	152	242	289	242	136	1,061	
Pollination[c] (number of apiary sites)	170	349	586	363	1,007	2,475	
Cultural services							
Recreation[a] (number of visits)	n.a.	n.a..	n.a.	n.a.	n.a.	34,000,000	
Abiotic services							
Minerals[c] (ha mining licenses)	1,009	2	6,723	642	6,364	14,738	

n.a. indicates data not available at the RFA region level
(a) Plantation timber data is for 2017-18, carbon data is for 2017, tourism data is aggregated from 2016-17 data (parks) and 2019 data (state forests). (b) Firewood collected by households from state forests. (c) Indicator reported rather than actual physical quantity of ecosystem service. (d) Total is less than the sum of RFA regions, as some localities receive water flow regulation services from multiple RFA regions.

Table 8 Monetary flow of ecosystem services from forests in RFA regions (2018 estimate unless otherwise stated)

	Central Highlands	East Gippsland	Gippsland	North East	West	Total	Confidence
Ecosystem services							
Provisioning services							
Water ($ million)	311-806	11	95-96	261	96	774-1,270	
Native timber ($ million)	21	3	3	1	-	28	
Plantation timber[a] ($ million)	n.a.	n.a.	n.a.	n.a.	n.a.	54	
Firewood[b] ($ million)	n.a.	n.a.	n.a.	n.a.	n.a.	3-7	
Honey ($ million)	n.a.	n.a.	n.a.	n.a.	n.a.	3-4.5	
Fodder	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
Regulating services							
Water flow regulation ($ million)	n.a.	n.a.	n.a.	n.a.	n.a.	97	
Soil retention ($ million)	655-1,216	0-1,736	460-1,668	1,759-2,834	179-568	3,054-8,021	
Carbon sequestration[a] ($ million)	356	399	1,019	704	528	3,006	
Carbon storage	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
Pollination ($ million)	n.a.	n.a.	n.a.	n.a.	n.a.	0.8-1	
Cultural services							
Recreation[a] ($ million)	n.a.	n.a..	n.a.	n.a.	n.a.	905	
Abiotic services							
Minerals	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	

n.a. indicates data not available at the RFA region level
(a) Plantation timber data is for 2017-18, carbon data is for 2017, tourism data is aggregated from a 2014 study (parks) and 2019 study (state forests). (b) Firewood collected by households from state forests.

Provisioning services

Water provision

Forests in RFA regions capture, filter and release clean water to natural, human modified and human created water supply systems. The direct user of this ecosystem service is the Victorian water industry. Water is then supplied to and used by households, industry (particularly the agriculture industry) and government (including for environmental and recreational purposes).[23]

Figure 6 shows average annual water yield across RFA regions. In 2018, the quantity of water provision from forests in RFA regions was 6,432 gigalitres of water. The value of this ecosystem service is estimated at $0.8–1.3 billion in 2018.

Water provision can vary significantly from year to year, as flows of this ecosystem service are strongly dependent on climate and rainfall. This is evident in Table 9, which reports water provision in physical and monetary terms over the past five years. There is a spike in water provision in 2016 which was Victoria's wettest year since 2011[24], followed by lower flows in 2017 and 2018 as the north and east of the state moved into drier conditions.

Over the full time period modelled for this study (2008–2018), water provision from forests in RFA regions averaged 11,838 gigalitres per year, with an estimated value of $1.3–2 billion per year.

23. In this study, provision of water from forests to water supply systems has not been matched with abstractions for consumptive use, which will typically be less than water yield over a sufficient time period under sustainable management. This is a potential area for future work in Victoria.

24. Bureau of Meteorology 2019, 'Victorian in 2016: A wet and warm year', accessed October 2019 at http://www.bom.gov.au/climate/current/annual/vic/archive/2016.summary.shtml

Figure 6 Average annual water yield across RFA regions (2008–2018)

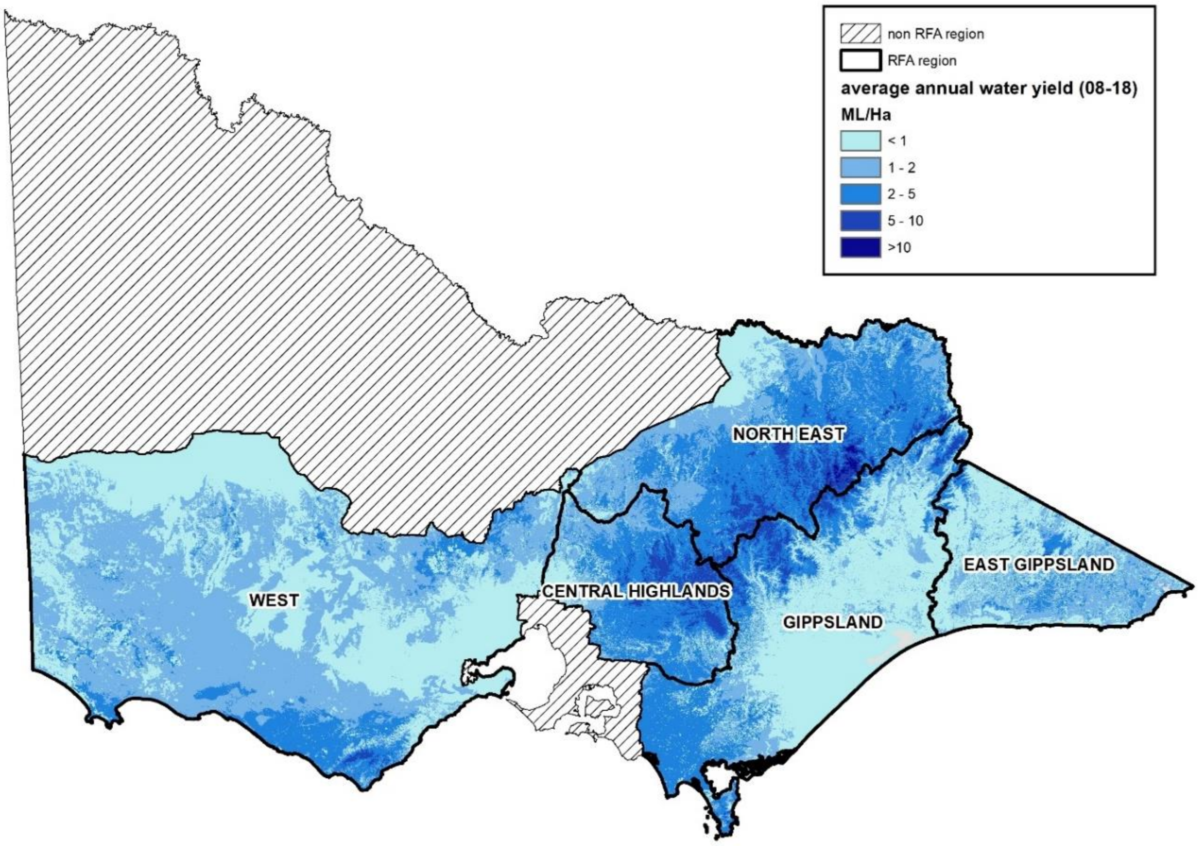


Table 9 Water provision from forests in RFA regions in physical and monetary terms (2014–2018)

	2014	2015	2016	2017	2018
Physical (ML)					
Central Highlands	2,238,798	1,511,839	2,998,349	2,262,309	1,747,530
East Gippsland	2,069,085	2,238,008	1,971,093	83,314	144,802
Gippsland	2,355,894	1,807,558	4,476,587	1,734,527	1,115,835
North East	3,869,636	2,597,293	9,424,965	4,112,990	2,414,068
West	900,693	434,486	2,474,916	1,255,449	1,009,526
Total	*11,434,105*	*8,589,184*	*21,345,910*	*9,448,589*	*6,431,762*
Monetary ($)[a]					
Central Highlands	316,839,716	276,717,767	684,729,408	264,313,708	310,684,656
East Gippsland	75,782,505	123,042,625	157,735,578	4,154,583	10,863,553
Gippsland	168,496,227	143,865,181	604,186,400	112,747,747	94,915,355
North East	234,043,934	249,408,095	1,636,046,911	200,605,095	261,205,474
West	56,693,907	33,221,099	346,201,578	68,854,489	95,940,966
Total	*851,856,289*	*826,254,767*	*3,428,899,875*	*650,675,621*	*773,610,005*

(a) Monetary estimates reported in this table are lower bound estimates. See Appendix A for discussion of valuation methods and upper bound estimates.

Biomass for timber

Forests in RFA regions provide biomass which is harvested for use in timber products. The direct user of this ecosystem service is the Victorian timber industry which harvests timber from native and plantation forests. Businesses and households benefit from the production and consumption of timber products.

In 2018, native forests in RFA regions provided 1.2 million cubic metres of biomass for timber. While in the 2017-18 financial year, plantation forests in RFA regions provided 7.8 million cubic metres of biomass for timber. The value of this ecosystem service is estimated at $82 million.

These physical and monetary estimates include commercially harvested timber that is used for firewood. Across the state, VicForests[25] sold around 50,000 cubic metres of 'other' wood products in 2017-18, which is predominantly firewood.[26] The volume of plantation timber that is used for firewood in unknown.

Biomass for firewood (household collection)

Forests in RFA regions also provide biomass which is collected for firewood. The direct user of this ecosystem service is households who collect firewood from forests on public and private land. Households benefit from the use of firewood for heating, cooking and aesthetic enjoyment.

25. VicForests is the state-owned business responsible for the harvest and sale of timber from state forests.

26. VicForests 2018, *VicForests annual report 2017-18*, Melbourne, p. 13.

It is estimated that at least 45,000 cubic metres of firewood is collected by households each year from public forests in RFA regions. The value of this ecosystem service is estimated at around $2.7–6.8 million per year.

The volume of firewood collected by households from forests on private land is unknown.

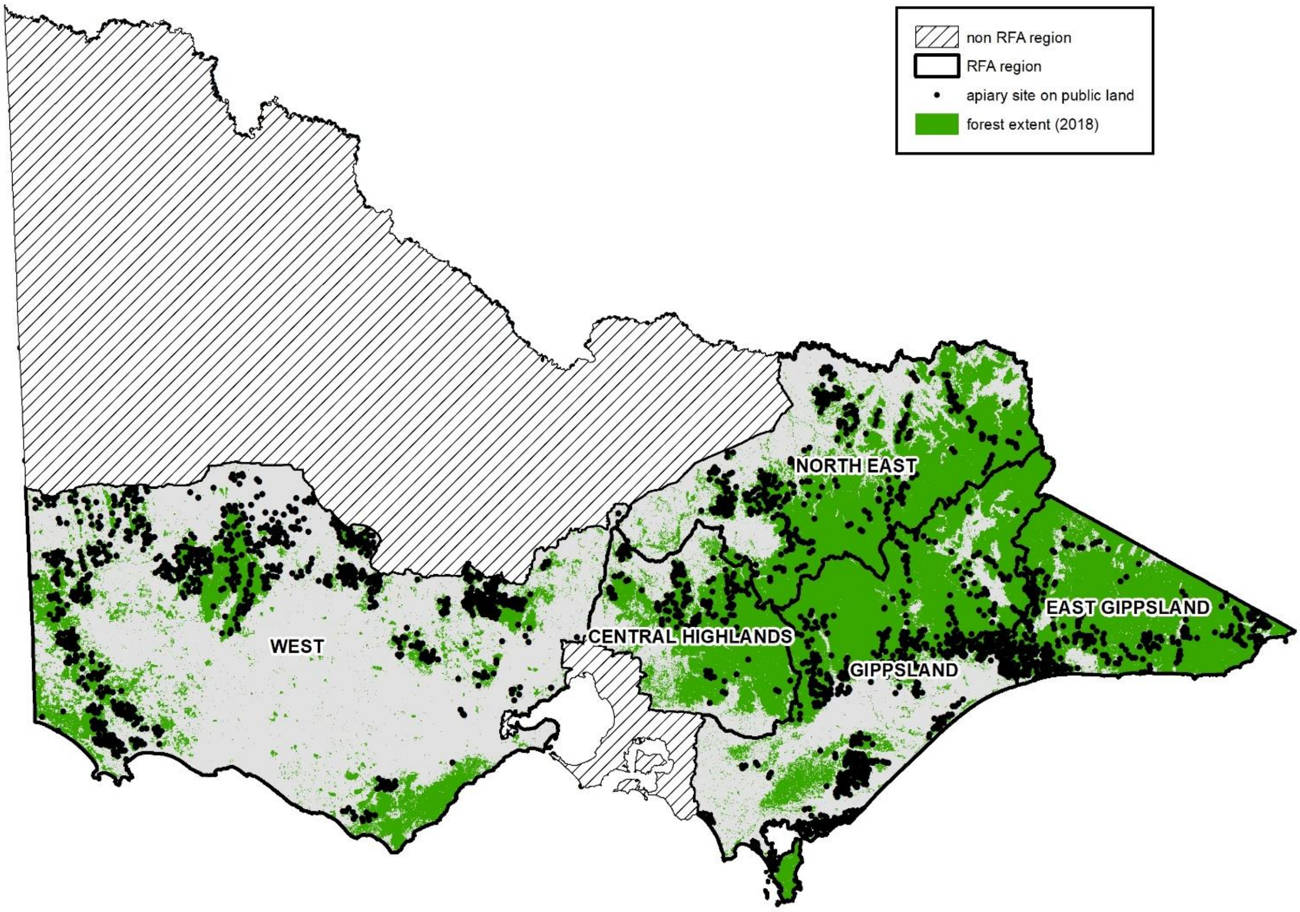
Honey

Forests in RFA regions support wild and managed bee populations that produce honey. Forest areas also provide physical space for hives. There is a clear correlation between forest extent and apiary sites on public land (see Figure 7).

The main user of this ecosystem service is the apiary industry which produces honey and other bee products. Households undertaking non-commercial beekeeping and honey production also use this ecosystem service.

Honey production dependent on forests in Victorian RFA regions is estimated at around 1,000-1,500 tonnes per year. The value of this ecosystem service is estimated at around $3-4.5 million per year.

Figure 7 Forest extent and apiary sites on public land across RFA regions

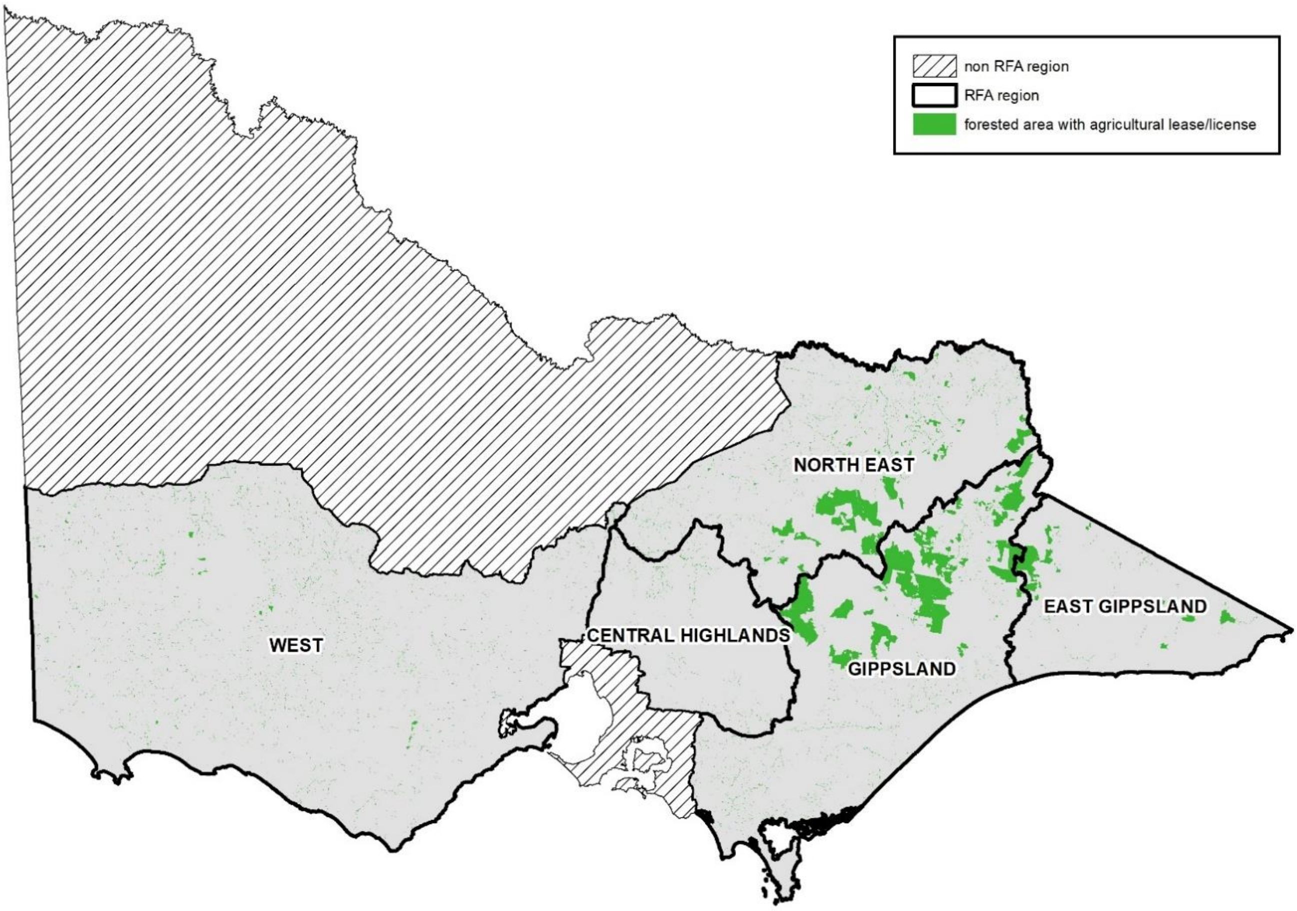


Fodder (for grazing)

Forests in RFA regions provide plant biomass (fodder) that is grazed by livestock in forests. The user of this ecosystem service is the agriculture industry which uses fodder as an input to livestock production.

Information on the quantity of fodder provided by forest ecosystems for grazing is not available. Licenses for agricultural use cover 494,391 hectares of forest across Victorian RFA regions (see Figure 8). This provides an indicator of the capacity of forests to provide fodder for grazing.

Figure 8 Area of public forest licensed for agricultural use across RFA regions



Box 8 Minerals: An abiotic service provided by forest areas

Ecosystem services do not represent the complete set of flows from the environment that contribute to economic and other human activity. Other flows, which are known as abiotic services, include the extraction of mineral and energy resources.

Information on abiotic services is often presented alongside ecosystem services. This is useful because ecosystem accounting can be used to organise information for assessing alternative uses of land, and often there are trade-offs between combinations of ecosystem and abiotic services that stem from alternative land uses.

Mineral resources is a key abiotic service that flows from forest areas within RFA regions. There are currently 85 mining licenses that intersect with forest areas across RFA regions. These licenses cover 14,738 hectares of forest. This provides an indicator of the potential capacity of forest areas to provide mineral resources as an abiotic service.

Regulating services

Water flow regulation

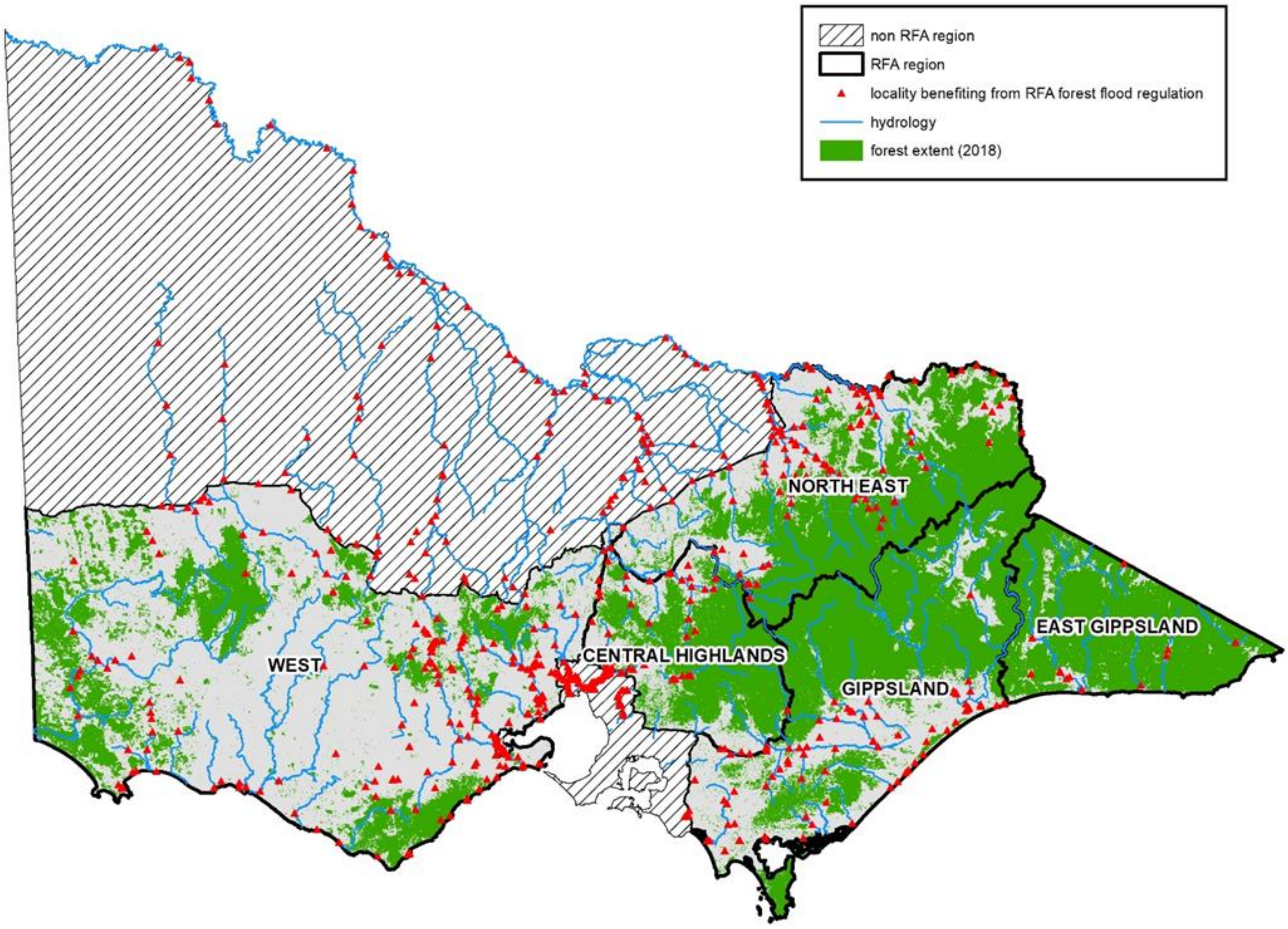
Forests in RFA regions regulate the flow of water, which helps to mitigate the impact of extreme rainfall events. This ecosystem service is used by households, industries and government who benefit from reduced occurrence or severity of river flooding.

Forests in RFA regions are estimated to provide water flow regulation services to 646 localities across Victoria, including in metropolitan Melbourne (see Figure 9). The quantity of service provided to each locality varies depending on the extent of forest in its catchment, catchment topography and climate.

A case study of Wangaratta in northeast Victoria indicates that forests in the Ovens catchment provide water flow regulation services estimated to prevent an average of 4 days of flooding per year, which has a value of around $4.8 million per year in avoided damages to property and infrastructure.

Extrapolating this case study out to other localities receiving water flow regulation services suggests that the minimum value of this ecosystem service may be $97 million across Victorian RFA regions. Note this is an indicative estimate only.

Figure 9 Victorian localities benefiting from water flow regulation services provided by forests in RFA regions



Soil retention (erosion prevention)

Forests in RFA regions provide soil retention services, as forest vegetation helps prevent erosion. Households, government and industry are all users of this service. For example, households or businesses in areas adjacent to forests may benefit from the prevention of landslides. In particular, the water industry benefits from avoided sediment erosion into water supply systems across the state.

In 2018, forests in RFA regions prevented 2.1 billion tonnes of soil erosion, compared to a counterfactual scenario where there was no land cover (i.e. bare earth).[27] Of this, 382 million tonnes of soil erosion to major waterways was prevented. Forests within the higher rainfall and steeper terrain areas of the state's Great Dividing Range provide the largest relative soil retention services (see Figure 10).

27. Under this counterfactual scenario soil erosion across the landscape is significant. It should be noted that other ecosystem types (such as grasslands) will also provide significant soil retention services.

The estimated value of this ecosystem service is $3.1–8 billion in 2018, based on the cost of artificially removing sediment from major waterways.

Like water provision, soil retention (erosion prevention) can vary significantly from year to year, as the flow of this ecosystem service is strongly dependent on climate and rainfall. This is evident in Table 10, which reports erosion prevention in physical terms over the past five years. Like water provision, there is a spike in erosion prevention in 2016 which was Victoria's wettest year since 2011[28], followed by lower flows in 2017 and 2018 as the north and east of the state moved into drier conditions.

Over the full time period modelled for this study (2008–2018), erosion prevention by forests in RFA regions averaged 782 million tonnes per year, with an estimated value of $6.6–16.4 billion per year.

28. Bureau of Meteorology 2019, 'Victorian in 2016: A wet and warm year', accessed October 2019 at http://www.bom.gov.au/climate/current/annual/vic/archive/2016.summary.shtml

Figure 10 Average annual avoided soil erosion across RFA regions (2008–2018)

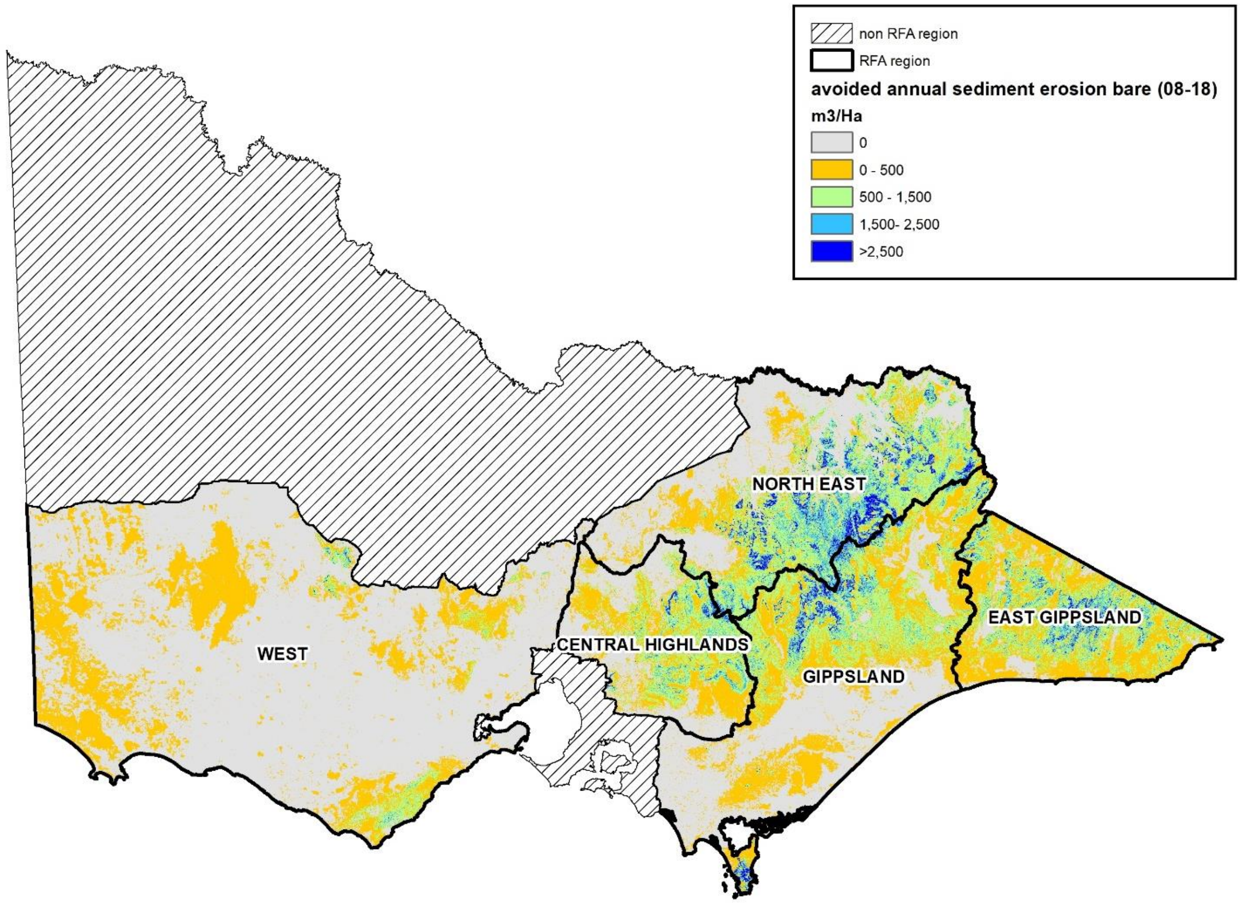


Table 10 Quantity of erosion prevention to major waterways by forests in RFA regions (tonnes, 2014–2018)

	2014	2015	2016	2017	2018
Central Highlands	75,425,174	37,375,170	84,074,829	108,141,596	57,892,772
East Gippsland	228,759,233	184,998,281	205,758,539	49,868,370	82,656,290
Gippsland	206,319,296	137,907,573	281,139,549	143,860,481	79,431,860
North East	215,162,527	162,685,538	450,780,716	313,000,325	134,943,335
West	17,934,620	18,381,944	42,424,690	32,548,708	27,033,342
Total	*743,600,849*	*541,348,506*	*1,064,178,322*	*647,419,481*	*381,957,598*

Carbon sequestration and storage

Forests in RFA regions remove carbon dioxide from the atmosphere and store it as organic carbon in plant biomass and soil. The users of the ecosystem service of carbon sequestration are the Victorian, Australian and global communities who benefit from reduced impacts of climate change.

In 2017, forests on public land in Victorian RFA regions sequestered 41 megatonnes of carbon, which is equivalent to 150 megatonnes of carbon dioxide. The value of this ecosystem service is estimated at $3 billion in 2017.

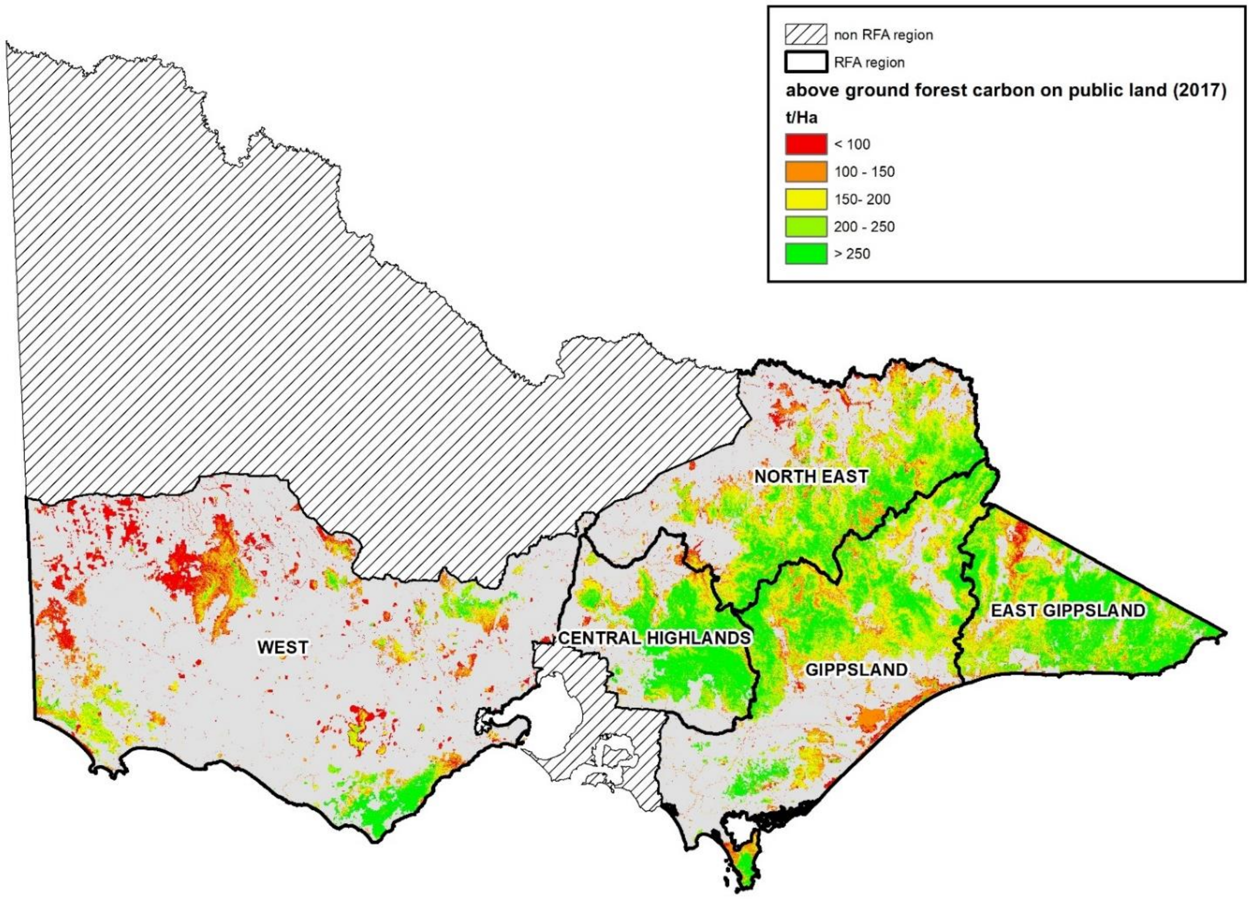
Carbon sequestration can vary significantly from year to year, as the flow of this ecosystem service is related to disturbance events that impact on the condition of the ecosystem assets. Forests will typically generate a higher ecosystem service flow after bushfires, timber harvesting, or drought and degradation as vegetation regenerates. Over the past decade (2008–2017), carbon sequestration by forests on public land in RFA regions averaged 34 megatonnes per year and a value of $2.5 billion per year.

In addition to carbon sequestration, carbon storage can be considered a separate ecosystem service defined as the avoided flow of carbon resulting from maintaining the stock of carbon sequestered by an ecosystem.[29] Measuring this ecosystem service entails estimating the avoided carbon losses. That is, stored carbon that is at clear risk of being released in the short term. No service flow is recorded if stocks at risk of being released are actually released, but a positive service flow is recorded if stocks at risk remain in storage. In 2017, there were 1,061 megatonnes of above ground carbon stock in public forests across RFA regions (see Figure 11). However, analysis of the risk of carbon stock loss, and therefore estimation of avoided emissions, has not been undertaken for this study.

It is also useful to understand the net change in forest carbon stock, considering emissions and removals of carbon from forest ecosystems as well as sequestration. This is known as net ecosystem carbon balance. Between 2016 and 2017, the net change in forest carbon stock on public land in Victorian RFA regions was 26 megatonnes. Over the past decade (2008–2017), net ecosystem carbon balance averaged 17 megatonnes per year, indicating that carbon sequestration by forests has been greater than carbon emissions/removals from forests over this time period.

29. United Nations 2014, *System of Environmental-Economic Accounting 2012: Experimental ecosystem accounting*, United Nations, New York, p. 65.

Figure 11 Above ground carbon stock in public forests (2017)



Pollination

Forests in RFA regions support populations of native and introduced pollinators, which provide pollination services to industries and to households. A direct user of this ecosystem service is the apiary industry which provides commercial pollination services to producers of pollination dependent crops. The agriculture industry and households are also direct users of wild pollination services. Businesses and households benefit from the production and consumption of pollination dependent crops and gardens.

Forests in Victorian RFA regions are estimated to contribute $0.8-1.0 million to commercial pollination services per year. This reflects the value of the ecosystem's contribution to the apiary industry, rather than the contribution of wild pollination to households and the agriculture industry. It therefore represents a lower bound estimate of the total value of pollination services from forests in RFA regions.

More broadly, commercial and wild pollination services are a crucial input to agricultural production in Victoria. A recent study estimated that the economic value of pollination to agricultural production in Victoria is $3–9 billion.[30]

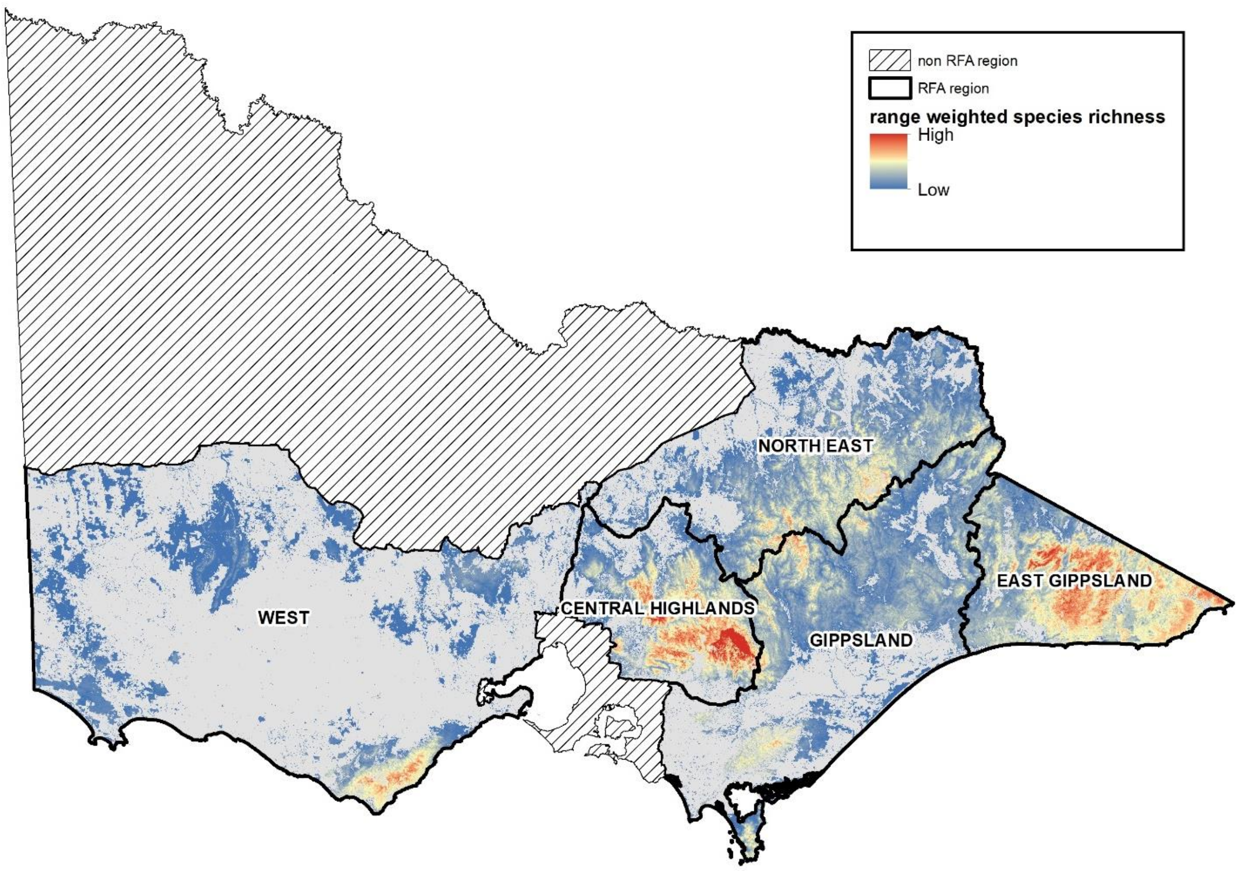
30. Karasinski, J 2018, *The economic valuation of Australian managed and wild honey bee pollinators in 2014-15*, Curtin University, Perth.

Habitat for species

Forests in RFA regions provide habitat for plants and animals and support the maintenance of biodiversity. The 'users' of this ecosystem service are the Victorian, Australian and global communities who value the existence of ecosystems, biodiversity and particular species. Including a measure of habitat for species ensures that this is represented and communicated, alongside other ecosystem services.

There are many different metrics that could be included in an ecosystem accounting framework. This section presents range weighted species richness data.[31] Differences can be seen across RFA regions (see Figure 12). On average, woody vegetation (forests) in the Central Highlands and East Gippsland RFA regions provide high proportions of habitat per spatial unit for threatened species that are acutely affected by timber harvesting, compared to the West RFA region. On average, forests in the Gippsland and North East RFA regions provide high proportions of habitat per spatial unit compared to the West RFA region, but low proportions compared to the Central Highlands and East Gippsland RFA regions.

Figure 12 Range weighted species richness across Victoria



31. Arthur Rylah Institute Integrated Biodiversity Values Model. See Appendix A for further discussion.

Air filtration

Forests in RFA regions provide an air filtration service by capturing airborne pollutants (such as particulate matter) and removing them from airsheds. The direct user of this ecosystem service is communities in proximity to forests who benefit from improved health and amenity due to better air quality.

Although forests are known to provide air filtration services, the quantity of pollutants removed from airsheds by forests in RFA regions, and the value of this ecosystem service, has not been estimated in this study.

Pest and disease control

Forests in RFA regions provide natural pest and disease control services by supporting species that are natural enemies of pest species. The key users of this ecosystem service are the agriculture industry and households that maintain gardens and benefit from reduced pests and disease.

Although forests are known to provide natural pest and disease control services, the quantity and value of this ecosystem service has not been estimated in this study.

Cultural services

Opportunities for recreation

Forest ecosystems provide opportunities for recreation and tourism. The key users of this ecosystem service are people who visit forests and the tourism industry.

It is estimated that there are around 34 million visits to forests on public land within RFA regions. This includes an estimated 11.5 million visits to state forests and 22.5 million visits to parks. The contribution of forest related tourism to gross state product is estimated at around $905 million per year.

Undertaking recreation and spending time in forests can also contribute to improved health and wellbeing. The contribution of forests to health and wellbeing benefits has not been estimated in this study. However, in 2015 it was estimated that 750,000 people per year visit non-metropolitan parks across Victoria to do physical activity. The value of this was estimated at $118 million in terms of avoided healthcare costs and productivity impacts.[32]

Opportunities for social and community connection

In addition to providing opportunities for recreation and sightseeing, forests provide opportunities for social and community connection and contribution. Forests in RFA regions provide opportunities for people to connect and participate in social and community activities. This is similar to (and may overlap with) opportunities for recreation, but specifically relates to people forming social connections or contributing to the community. These experiences are supported or enhanced by the environmental amenities that forests provide, although it is difficult to isolate the contribution of the ecosystem itself. The quantity and value of this ecosystem service has not been estimated in this study. However, it has been estimated that people spend over 200,000 hours volunteering in parks each year, which has an estimated value of over $6 million per year.[33]

32. Department of Environment, Land, Water and Planning & Parks Victoria 2015, *Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne, pp. 103-111.

33. Department of Environment, Land, Water and Planning & Parks Victoria 2015, *Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne, pp. 114-115.

Opportunities for cultural heritage connection

Forests in RFA regions encompass landscapes and sites of cultural and historical significance that Victorian, Australian and global communities value as part of their heritage. Forests provide immense value to Traditional Owners and Aboriginal communities, as well as providing heritage value to non-Aboriginal Victorians.

Opportunities for cultural heritage connection are not always provided solely by ecosystems: forest ecosystems combine with other attributes (such as historic structures and artefacts) to deliver benefits in the form of opportunities to connect with culture and heritage. However, forest ecosystems support and enhance connections, allowing place-based experiences rather than preservation in museums or other contexts. The quantity and value of this ecosystem service has not been estimated in this study. However, the value of non-Aboriginal heritage conservation in parks has previously been estimated at $6-23 million per year.[34]

Amenity

Forests in RFA regions provide amenity services to surrounding residents, enabling a range of personal and community benefits. This includes both use value from having closer proximity to access forests or gaining health and enjoyment benefits from viewing forests, as well as non-use value from knowing that forest ecosystems are nearby. The quantity and value of this ecosystem service has not been estimated in this study. However, in 2013 there were 38,000 immediate neighbours to national and state parks and 47,000 immediate neighbours to conservation reserves – a total of 85,000 immediate neighbours.[35] Much of the area of parks and conservation reserves adjacent to properties is forested.

Education and knowledge

Forests in RFA regions provide unique ecosystems that are inputs to research and education activities. This is used by the education and research sectors, and directly benefits people who visit or study forests for education and research purposes. Victorian, Australian and global communities benefit from education and research outcomes (through progress in knowledge or technology). The quantity and value of this ecosystem service has not been estimated in this study.

34. Department of Environment, Land, Water and Planning & Parks Victoria 2015, *Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne, pp. 118-119.

35. Department of Environment, Land, Water and Planning and Parks Victoria 2015, *Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne. p. 113-4.

Box 9 Future flows of ecosystem services

The analysis and accounts presented in this study track historical change and present a snapshot of flows of ecosystem services in 2018 (or other years where specified).

Populating accounts over time would enhance understanding of how flows of ecosystem services are changing, and the linkages between this and ecosystem extent and condition. However, the ability to meaningfully update accounts is constrained by the availability of temporal biophysical and socioeconomic data. This is a potential area for future work that could inform decision-making on the management of Victoria's forests into the future.

Conceptually, there are key factors which influence flows of ecosystem services:

- Change in ecosystem extent can impact on supply of ecosystem services. For example, a reduction in the area of forest in a catchment will reduce supply of soil retention services.
- Change in ecosystem condition can impact on supply of ecosystem services. For example, a reduction in the condition of a forest may reduce supply of recreation services as it becomes less appealing to visitors.
- Changes in the economy and community can impact on supply and use of ecosystem services. For example, population growth in a city adjacent to a forest may lead to more people receiving benefits from clean air.

Use of ecosystem services by industries

This section outlines the linkages between forests and industries in an ecosystem accounting framework, and discusses key industries in Victoria that use ecosystem services generated by forests. Information on the employment and economic contribution of these industries is presented. These values are different to the value contributed by ecosystems that is assessed in this study, as industries combine ecosystem services with other inputs such as capital and labour to produce goods and services in the economy. For this reason, and to avoid double counting, the value of industry contributions should not be aggregated with the value of ecosystem contributions. This study has not attempted to attribute the employment and economic contribution of industries to RFA regions, rather statewide information in presented.

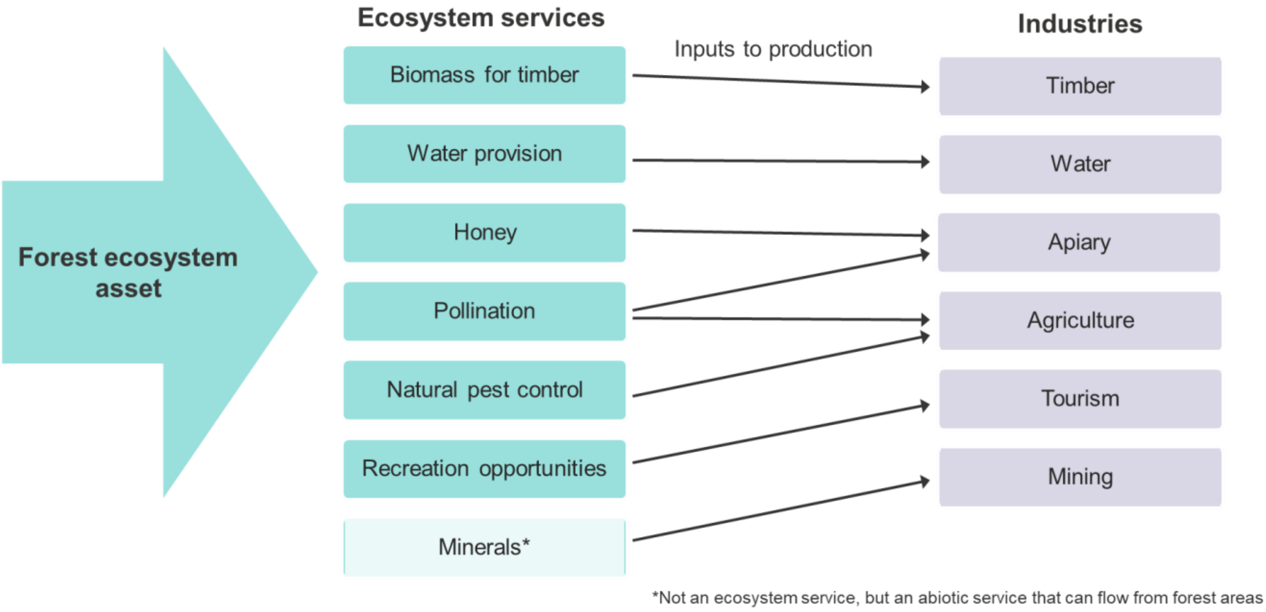
Like the community, industries rely on the provision of ecosystem services by forests. For many industries the linkages to ecosystems are complex and indirect. For example, the accommodation and food services industry uses water as an input to production, which is supplied by the water industry which is a direct user of the ecosystem service of water provision; or the tourism industry may benefit from a longer snow season due to the sequestration and storage of carbon by forests which contributes to climate change mitigation.

However, some industries directly use ecosystem services as inputs to production. Ecosystem services are combined with other inputs such as labour and capital to produce goods and services. Ecosystem services contribute to the value industries add in the economy, and the socioeconomic benefits they provide such as employment.

In the context of Victorian forests, industries that directly use ecosystem services include the timber industry, the water industry, the tourism industry, the apiary industry and the agriculture industry. The mining industry is a direct user of the abiotic services of mineral provision from forest areas. Figure 13 provides a stylised model of the linkages between forests and these industries via their use of ecosystem services.

Understanding the linkages between forests and industries provides clearer information on the contributions ecosystems make to industries, and how these industries in turn add value and generate employment in the Victorian economy. This section discusses industries that are key users of ecosystem services from forests.

Figure 13 Stylised model of how industries use ecosystem services as inputs to production



Timber industry

The timber industry is a key user of ecosystem services from forests in RFA regions, primarily the provision of biomass for timber. The Victorian timber industry comprises native forests and plantations which are grown and harvested (primary production); the logs, including timber imported from outside of Victoria, which are then processed into primary products such as sawn timber, woodchips, pulp and paper (primary processing); and the primary products which are then sold for further processing into secondary products such as furniture and paper packaging (secondary processing).[36]

The Victorian timber industry is almost fully reliant on the provision of biomass for timber from forests (native and plantation) in RFA regions, with only a small amount of timber sourced from outside Victoria. The plantation timber industry also uses other ecosystem services as inputs to production, such as water.

In 2017 and 2018, studies by the University of Canberra and EconSearch, for Forest and Wood Products Australia, estimated the contribution of the timber industry to the Victorian economy.[37] The studies draw on data from a range of sources including a 2017 forest industry survey[38], the Australian Bureau of

36. Schirmer, J, Mylek, M, Magnusson, A, Yabsley, B & Morison, J, 2018 *Socio-economic impacts of the forest industry – Victoria (exc. the Green Triangle)*, University of Canberra, Canberra, p. 3.

37. Schirmer, J, Mylek, M, Magnusson, A, Yabsley, B & Morison, J, 2017, *Socio-economic impacts of the forest industry – Green Triangle*, University of Canberra, Canberra; Schirmer, J, Mylek, M, Magnusson, A, Yabsley, B & Morison, J, 2018, *Socio-economic impacts of the forest industry – Victoria (exc. the Green Triangle)*, University of Canberra, Canberra.

38. The forest industry survey was conducted between February 2017 and May 2017 and surveyed forest industry businesses operating in Victoria. Of 156 key businesses (including nurseries, plantation management businesses, silvicultural contractors, harvest and haulage contractors, and wood and paper processors), 62 per cent (96 businesses) completed the survey. Of those businesses, 32 businesses completed every question, including most large businesses operating in the industry, and 64 completed a shorter version over the phone. Most non-participants (60 businesses) managed smaller businesses, particularly contracting businesses, with data on these businesses gathered from industry experts, other businesses, and publicly available information. One

Statistics (ABS) Census of Population and Housing, and economic modelling using the RISE (Regional Industry Structure and Employment) input-output model. These studies represent the most comprehensive information available on the economic contribution of the Victorian timber industry.

The timber industry was estimated to directly add $597.5 million to the Victorian economy (excluding the southwest Green Triangle region[39]) and support 5,115 full time equivalent jobs up to the point of sale of primary processed products – see Table 11.[40] Jobs in primary production and processing are estimated to be largely dependent on native forest and plantations grown in Victoria. Of the 5,115 jobs, around half (2,437 jobs) are generated from softwood plantations, a third (1,639 jobs) from native forests, around ten per cent (457 jobs) from hardwood plantations, and the remainder from native forests or plantations interstate.

The economic contribution of the timber industry in the Green Triangle region of Victoria and South Australia was estimated separately. The industry was estimated to directly add $97.7 million to the economy in the Victorian Green Triangle region, and support 536 jobs up to the point of sale of primary processed products.

Table 11 Direct employment and economic contribution of the timber industry

Region	Gross value added ($ million)	Employment (FTE jobs)
Central Highlands and Gippsland[a]	290.9	2,830
North Central[b]	115.1	1,002
Western (excluding Green Triangle region)[c]	90.4	650
Melbourne and rest of Victoria (excluding Green Triangle region)	101.1	633
South west Green Triangle region[c]	97.7	536

(a) Includes Central Highlands, Gippsland and East Gippsland RFA regions. (b) Includes North East RFA region. (c) Includes West RFA region. Source: Schirmer, J, et al 2017 and 2018.

Of the jobs in primary production and processing of timber from native forests, specific estimates were made for each RFA region – see Table 12. This was done by tracing the flow of timber from forests in each RFA region to the mills that use this timber, based on public information and industry surveys. Over 65 per cent of jobs are reliant of native timber harvested from the Central Highlands, followed by East Gippsland (15 per cent) and Gippsland (12 per cent).

Table 12 Estimated employment (in primary production and processing) reliant on native timber harvested from RFA regions

RFA region	Employment (FTE jobs)
Central Highlands	1,060 – 1,170
East Gippsland	230 – 260

limitation of the forest industry survey is the small number of businesses that completed the full survey, at only 32 out of 156 key businesses (21 per cent). However, these 32 businesses included most of the large businesses operating in the industry. Data from the forest industry survey have reasonable consistency with ABS Census of Population and Housing data

39. The 'Green Triangle' region spans the border between Victoria and South Australia.

40. Schirmer, J, Mylek, M, Magnusson, A, Yabsley, B & Morison, J, 2018, *Socio-economic impacts of the forest industry – Victoria (exc. the Green Triangle)*, University of Canberra, Canberra, p. 19.

Gippsland	190 – 210
North East	70 – 80
West	30 – 40

Note that not all jobs are located within each RFA region, as estimates include all jobs (in primary production and processing) reliant on native timber harvested from the region, irrespective of whether mills are located within the region.
Source: Adapted from Schirmer, J, 2018.

A further 9,360 direct jobs were estimated to be supported by secondary processing activities using wood and fibre from within Victoria and imported from interstate and overseas.[41] The proportion of these jobs that are dependent on native forest and plantation grown in Victoria is unknown. This indicates a total of 14,474 jobs in primary production, primary processing and secondary processing, which broadly aligns with 2016 Census data reporting a total of 15,015 people employed in the Victorian forestry sector.[42]

According to ABS Census data, there was a 25 per cent decline in Victorian forestry sector jobs between 2011 and 2016. Forestry sector employment as a proportion of total employment in Victoria declined from 0.8 per cent to 0.6 per cent. However, a closer analysis of the figures reveals a more nuanced picture. While there was a 29 per cent decline in employment in wood and paper product manufacturing, there was a 22 per cent increase in employment in primary production. The growth in primary production was driven in part by growth in harvest and haulage of hardwood plantations.

Tourism industry

The tourism industry is a key user of ecosystems services from forests in RFA regions, primarily opportunities for recreation and sightseeing in forests. The condition of forest ecosystems is important, with visitors attracted to healthy forests.

Tourism is a significant economic driver for Victoria, directly contributing $11.3 billion to the economy and over 140,000 full and part-time jobs in 2016-17.[43] Tourism associated with forests makes up part of the overall figures. People visit forests on public land on day or overnight trips, coming from within Victoria, interstate or overseas. Expenditure associated with these visits adds value to the Victorian economy and creates employment, including in regional areas.

A 2014 study estimated the economic contribution of tourism associated with Victorian parks. In 2010-11, park tourism was estimated to directly contribute $491 million to gross state product and directly provide 7,921 full time equivalent (FTE) jobs (see Table 13).[44] This study focused on parks, so would overestimate economic contribution of *forests* in parks, as forests are only part of the reason people visit parks. People are also motivated by attributes such as rivers, ocean and mountain landscapes.

41. Schirmer, J, Mylek, M, Magnusson, A, Yabsley, B & Morison, J 2018, *Socio-economic impacts of the forest industry – Victoria (exc. the Green Triangle)*, University of Canberra, Canberra, p. 18.

42. The Forestry sector is defined as the workforce employed in Forestry and Logging, Forestry Support Services, Wood Product Manufacturing, and Pulp and Paper Product Manufacturing, and excludes jobs in timber wholesaling.

43. Department of Economic Development, Jobs, Transport and Resources 2018, *Economic contribution of tourism in Victoria 2016-17*, State of Victoria, Melbourne.

44. Deloitte 2014, *The economic contribution of tourist visitation to Victorian parks: Valuing the tourism services provided by Victorian parks*, report prepared for Parks Victoria.

However, forests and other native vegetation in landscapes are a key reason people visit parks and state forests.

In 2019, a study estimated the economic contribution of tourism associated with state forests across Victoria. In the six months between February and July 2019, state forest tourism was estimated to directly contribute $345.5 million to gross state product and directly provide 3,469 FTE jobs.[45]

Table 13 Economic contribution of park tourism (2010–11)

Tourism region	Direct GRP $ million	Direct employment (FTE)
Yarra Valley and Dandenong Ranges	23	449
Gippsland	31	538
Victoria's High Country	25	421
Grampians	15	287
Great Ocean Road	40	695
Daylesford and the Macedon Ranges	4	77
Goldfields	5	115
Melbourne	298	4,535
Mornington Peninsula	21	351
Phillip Island	6	97
Murray	22	357
Total	491	7,921

Source: Deloitte 2014

Water industry

The water industry is a key user of ecosystem services from forests in RFA regions, mainly water provision and erosion prevention, as well as water filtration (which has not been separately assessed in this study).

Forests in RFA regions capture water and release it to natural, human modified and human created water supply systems. Water is then supplied to and used by households, industry (particularly the agriculture industry) and government (including for environmental and recreational purposes). However, the water industry can be considered the direct user of the ecosystem service.

More broadly, the 'water supply, sewerage and drainage services' sector is estimated to contribute $3.9 billion (or 1 per cent) of total value added in Victoria and around 7,700 FTE jobs.[46]

45. Quantum Market Research 2019, *Understanding state forest visitation and tourism*, report prepared for the Department of Environment, Land, Water and Planning.

46. REMPLAN Economy 2019.

Apiary industry

The apiary industry is a key user of ecosystem services from forests in RFA regions, mainly honey provision and pollination. Apiarists use these as inputs to commercial honey production and commercial pollination services.

The industry relies on access to floral resources in forests to produce honey and to physical sites on public land which are used for storing hives.

Agriculture industry

The agriculture industry is a key user of ecosystem services from forests in Victorian RFA regions, including wild pollination services and natural pest control. The agricultural industry also uses goods and services provided by the apiary industry (commercial pollination services) and the water industry (water supply), which in turn use ecosystem services generated by forests.

More broadly, the 'livestock, grains and other agriculture' sector is estimated to contribute $8.6 billion (or 2.1 per cent) of total value added in Victoria and around 56,400 FTE jobs.[47]

Mining industry

The mining industry is the key user of the abiotic service of provision of minerals, which can flow from areas of land within forests. More broadly, the mining sector is estimated to contribute $3.6 billion (or 0.9 per cent) of Victoria's total value added and around 7,200 FTE jobs.[48]

47. REMPLAN Economy 2019.
48. REMPLAN Economy 2019.

Conclusion

Understanding the linkages between ecosystems and the economy and society is integral to our knowledge of forests and to policy and management decisions. This study shows that forests provide a diverse range of ecosystem services that flow to Victorian communities and industries.

As the first comprehensive assessment of forest ecosystem services across Victorian RFA regions, this study establishes a framework that can be used to monitor trends in ecosystem extent and condition and flows of ecosystem services over time. It provides a reference point against which future ecosystem accounts can be compared.

The findings presented in this report provide an initial, indicative and conservative estimate of the quantity and value of ecosystem services provided by forests in Victorian RFA regions. The value of some ecosystem services is significant; particularly water provision, water flow regulation, soil retention, carbon sequestration and opportunities for recreation.

This study is an assessment of the total annual value of current flows of ecosystem services from forests. However, information presented in ecosystem accounts has the potential to inform analyses of how flows of ecosystem services may change over time, under different scenarios, and the resulting marginal change in value. Ecosystem accounting provides a spatial framework that can inform scenario analysis and help in understanding how flows of ecosystem services may change over time and across different parts of Victoria.

Overarching findings of this study are:

- Forests provide a diverse range of provisioning, regulating and cultural ecosystem services. RFAs cover almost 80 per cent of forests in Victoria, meaning that most forest ecosystem services flow from within RFA regions.
- Ecosystem services flow from forests to the economy and society, where they are used by industries and communities. Key Victorian industries that use forest ecosystem services as inputs to production are the timber, tourism, water, apiary and agriculture industries.
- Although communities and industries benefit from use of ecosystem services, their value is either not captured in standard measures of economic activity such as gross state product or is not clearly attributed to ecosystems.
- Some ecosystem services have significant value that is fully or partially captured in economic measures such as industry value added and gross state product, but is not clearly attributed to ecosystems. This includes the ecosystem services of water provision and opportunities for recreation.
- Other ecosystem services have significant value that is not captured in economic measures. This is particularly the case for regulating services such as soil retention, water flow regulation and carbon sequestration.
- The benefit people gain from visiting and recreating in forests is influenced by access to built assets and amenities (such as parking, picnic and camping sites and trails), as well as healthy ecosystems.

Undertaking this study highlighted several gaps and limitations in data and methods:

- While timeseries data is available or can be modelled for some ecosystem services, this is not the case for other ecosystem services. This limits the ability to produce meaningful ecosystem service flow accounts over time.

- The availability and quality of data varies between ecosystem services. This means there is a significant variation in the certainty of quantity and value estimates for different ecosystem services.
- Forest ecosystem condition was not explicitly linked to flows of ecosystem services in this study. However, a measure of ecosystem condition and the relationship between this and the provision of ecosystem services would help in understanding and modelling how ecosystem service flows change over time.
- Some ecosystem services (including several cultural services) could not be quantified or valued due to a lack of environmental or socioeconomic data. However, this does not imply a lack of value, and it is important to ensure these ecosystem services are considered in decision making processes.

Glossary

Abiotic services	Contributions of the environment to benefits used in economic and other human activity that do not arise as a result of biophysical processes and other interactions within and between ecosystems.
AHGF	The Australian Hydrological Geospatial Fabric (Geofabric) registers the spatial relationships between important hydrological features such as rivers, water bodies, aquafers and monitoring points. It is created by the Australian Bureau of Meteorology.
ArcGIS	Geographical information system used to view, process and analyse spatial data
BioSim	Biophysical simulation model, a subset of the EnSym framework that models plant, soil, water and atmospheric interactions.
CICES	The Common International Classification of Ecosystem Services – a typology for classifying ecosystem services that was developed to support environmental-economic accounting.
Consumer surplus	A measure of the net benefits to consumers from the consumption of a good or service. It is the difference between the price consumers pay for a good or service and the price they are willing to pay.
CSDL	DELWP's Corporate Geospatial Data Library
Cultural services	Non-material ecosystem outputs that provide cultural, social, intellectual or health benefits to people through cultural and community connection, recreation and relaxation, and knowledge development.
DELWP	Victorian Department of Environment, Land, Water and Planning
DJPR	Victorian Department of Jobs, Precincts and Regions
Ecosystem accounting	Statistical framework for organising spatial biophysical data about ecosystem assets and ecosystem services, tracking changes in ecosystems over time, and linking to economic and other human activity. Ecosystem accounting can be in both physical and monetary terms.
Ecosystem assets	Spatial areas containing a combination of biotic and abiotic components that function together as a specific combination of ecosystem characteristics forming a system.
Ecosystem services	Ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity. Ecosystem services are often classified into provisioning, regulating and cultural services.
Ecosystem service flows	Quantity of services provided from ecosystem assets to beneficiaries in a period (typically a year).
EnSym	Environmental Systems Modelling Framework
Exchange value	The value at which goods or services are traded in a market. It is equal to the market price multiplied by the quantity transacted.

Externalities	The result of an activity (production or consumption) causing incidental costs or benefits to others with no corresponding compensation provided to or paid for by those accruing costs of benefits. Externalities can be positive (benefits) or negative (costs).
Gross state product	The total value of (market) goods and services produced within a state's borders in a specific period (typically a year). It is also measured at the national level (gross domestic product) and the regional level (gross regional product).
Gross value added	The value of output (goods and services) less the value of intermediate consumption used in producing that output. Gross value added can be measured for an area, industry or sector of an economy, and is often used to measure the contribution of individual industries to the gross product of a state or region (industry gross value added).
IBVM	Integrated Biodiversity Values Model
PLM25	Victorian Public Land Management data
Provisioning services	Material ecosystem outputs that provide benefits to people from the consumption of tangible goods and services. Examples include food, water and other raw materials.
Regulating services	Ecosystem functions that provide benefits to people from regulating climate, hydrologic, biogeochemical and other cycles. An example is the capacity of ecosystems to regulate climate and contribute to climate change mitigation.
RFA	Regional forest agreement
SDL	Sustainable diversion limit
SEEA	United Nations System of Environmental-Economic Accounting – common statistical framework for environmental-economic accounting. The central framework (environmental accounting) is an agreed statistical standard, while experimental ecosystem accounting is currently in development and being piloted around the world (including Victoria).
SILO	Queensland Department of Environment and Science daily national meteorological datasets
VFMP	Victorian Forest Monitoring Program
VLUIS	Victorian Land Use Information System

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Appendix A: Assessment of ecosystem services from forests

Provisioning services

Water provision

Description of ecosystem service and users

Forests in Victorian RFA regions capture water and release it to natural, human modified and human created water supply systems. This includes Melbourne's water supply system and regulated and unregulated systems across the state.[49] Water is then supplied to and used by households, industry (particularly the agricultural industry) and government (including for environmental and recreational purposes). The water industry is considered the direct user of the ecosystem service. This conceptualisation aligns with the approach proposed by Vardon et al. in the context of the Victorian Central Highlands.[50]

Supply of the water provision ecosystem service is strongly dependent on climate and rainfall, with greater flows in wet years. Forest ecosystems also influence the quality of water supplied by naturally filtering and purifying it, reducing the amount of sediment and pollutants that would otherwise reach waterways. Under different types of land cover – such as pasture or bare earth – the quantity of water provision may be greater, but the quality of water would be reduced.

Water filtration can be conceptualised as a separate regulating ecosystem service, which is not assessed in this study. Depending on the method used, the value of water provision is likely to capture some of the value of water filtration, as the quality of water is implicit in market prices. If water filtration was separately assessed, care would need to be taken to avoid double counting.

Forests ecosystems also regulate the flow of water, which is assed separately in this study as a regulating service.

Quantification of ecosystem service

Quantifying the water provision ecosystem service requires identifying the volume of water yield from forest ecosystems that flows into water supply systems, including Melbourne's system and regulated and unregulated systems across the state.

Water yield from forests is dynamically modelled from 2008 to 2018 and used to derive annual water yield for each RFA region. Water yield[51] is modelled using BioSim, which is the biophysical modelling toolbox of EnSym designed to simulate all major hydrological components of the water cycle. BioSim

49. Regulated systems are water systems where the flow of the river is regulated through the operation of major storages or weirs to secure water supplies. Unregulated systems are river systems where no major dams or weir structures have been built to regulate the supply, or extraction, of water for consumptive use.

50. Vardon, M, Keith, H & Lindenmayer, D 2019, 'Accounting and valuing the ecosystem services related to water supply in the Central Highlands of Victoria, Australia', *Ecosystem Services*, volume 39.

51. Yield for water provision comprises modelled surface runoff, sub-surface lateral flow and 60 per cent of recharge.

runs a suite of phenological based pasture, crop and forest growth models which simulate soil/water/plant/atmosphere interactions on a daily timestep.[52]

BioSim models water yield for each 100 metre grid cell in a spatial area, including forest cells and non-forest cells. BioSim interacts with ecological vegetation classes (EVCs) to model water yield for different vegetation types (such as mountain ash). Annual yield is calculated for each grid cell across the time period modelled.

Forest extent and condition is held constant across the period modelled (using 2018 forest extent) and all forests are assumed to be mature. Data on change in forest condition over time is not available, and EnSym by default is unable to model temporal changes in land cover during a model run. However, given ecosystem services are primarily being assessed at the scale of RFA regions, the lack of dynamic land cover modelling and forest condition change is unlikely to have a meaningful impact on relative findings.

Figure 14 shows average annual water yield (for the modelled period of 2008 to 2018) across RFA regions for both forest and non-forest areas. Yield ranges from less than 1 megalitre per hectare per year (in large areas of the West and Gippsland RFA regions), to more than 10 megalitres per hectare per year (e.g. in parts of the North East RFA region).

52. Beverly, C 2007, *Technical manual – models of the catchment analysis tool*, Department of Sustainability and Environment, State of Victoria, Melbourne.

Figure 14 Average annual water yield across RFA regions (2008–2018)

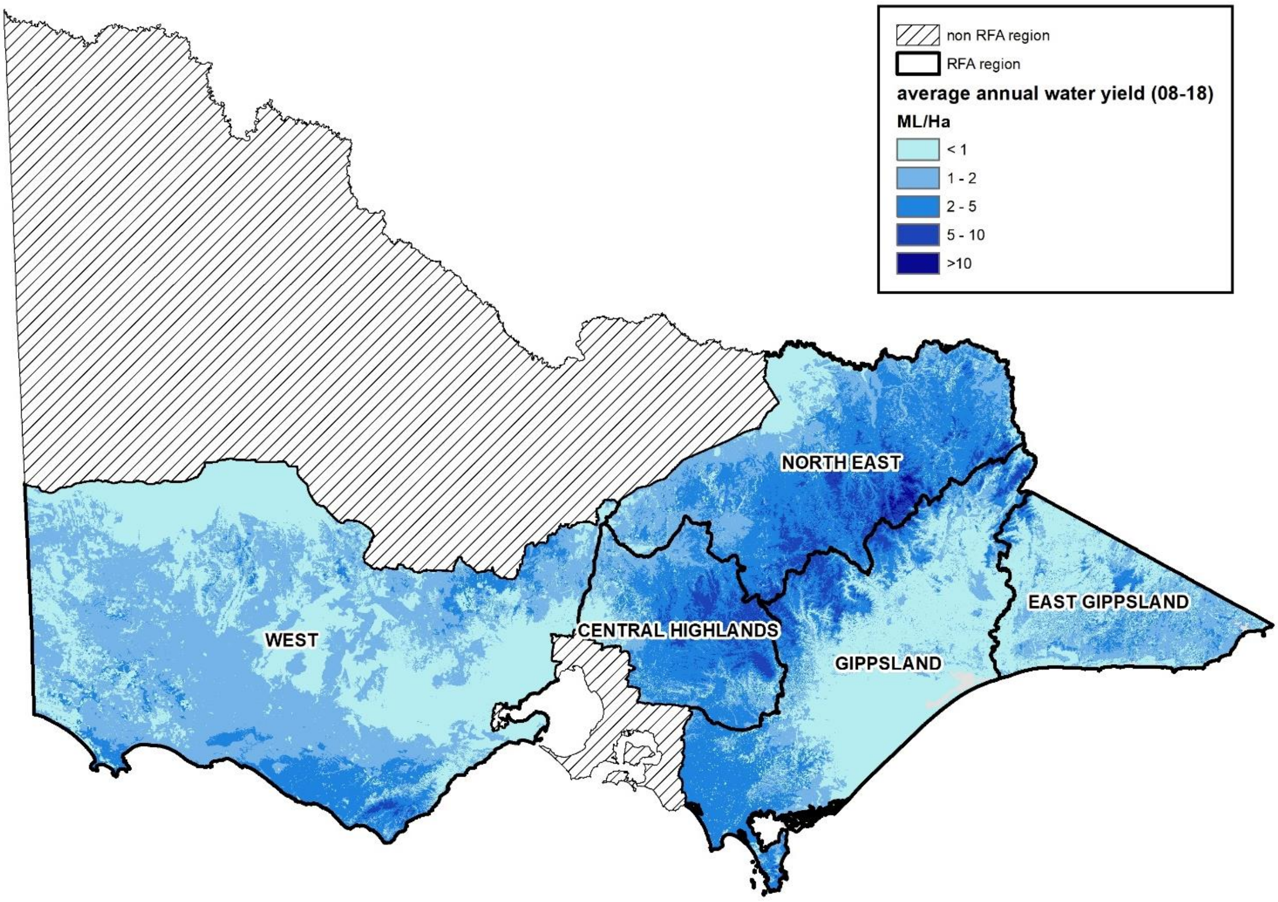
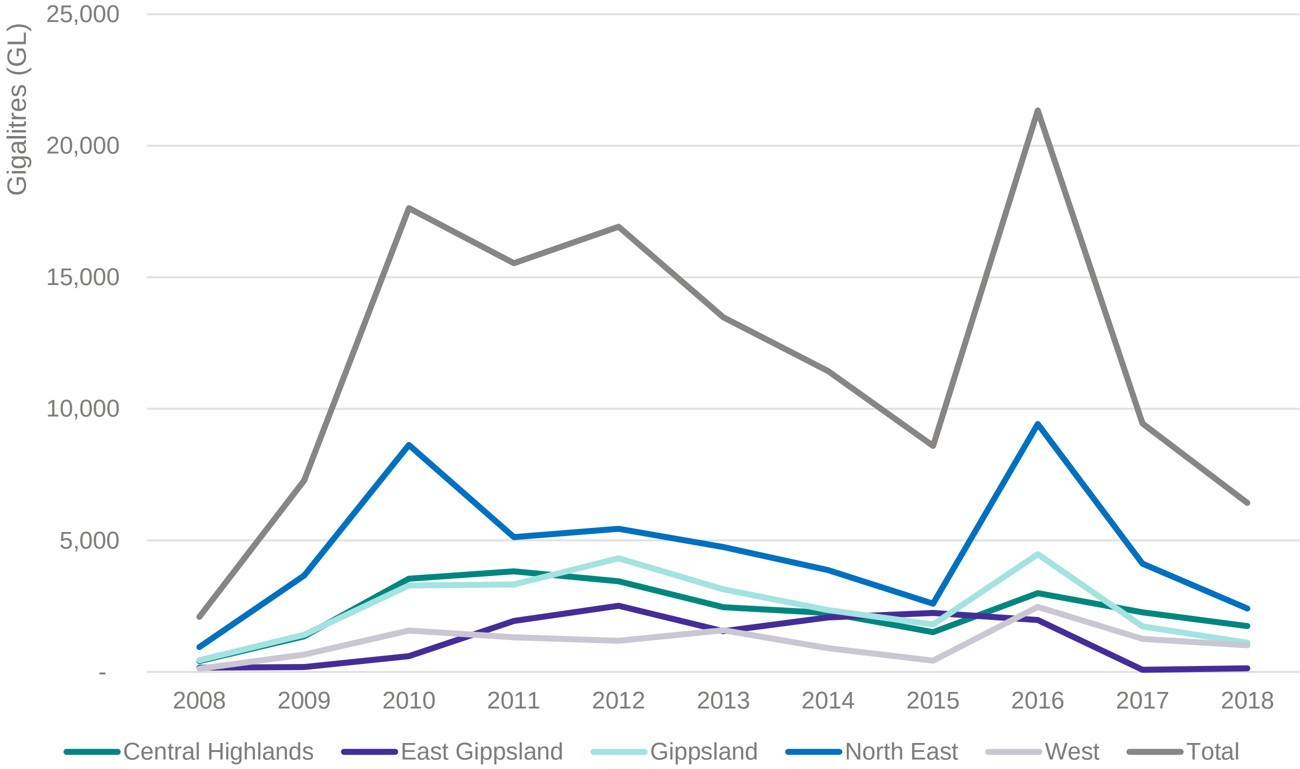


Figure 15 shows water yield from forests in RFA regions from 2008 to 2018 (water yield from non-forest areas is excluded). The underlying data is presented in Table 15. This represents the annual quantity of the ecosystem service provided by forests in different RFA regions. High rainfall years in 2010, 2012 and 2016 are evident. Water provision is most significant in the North East RFA region, which accounts for almost 40 per cent of total water provision from forests in RFA regions over time period modelled. The Gippsland and Central Highlands RFA regions supply the second and third greatest quantity of water provision, although in terms of quantity supplied per hectare the Central Highlands RFA region is comparable with the North East RFA region.

Figure 15 Quantity of water provision from forests in RFA regions (2008–2018)



BioSim models the flow of water across a spatial area from a grid cell of origin into specific water systems. This allows estimation of the quantity of water provision from forests to water systems that supply different parts of the state, which is integral to understanding the users of the ecosystem service and to valuation. Because water provision can be attributed to grid cells of origin, the quantity and value of the ecosystem service can be aggregated and reported by RFA region.

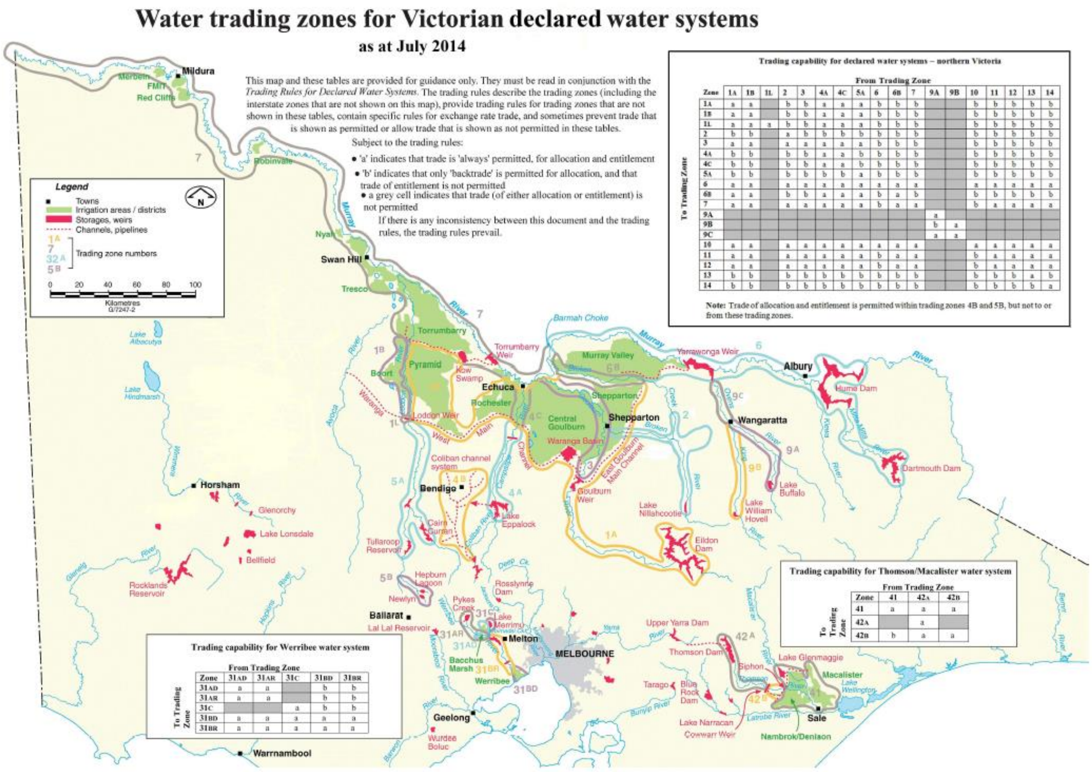
As discussed previously, water yield from forests flows into natural, human modified and human created water supply systems. Regulated systems are an example of human modified systems where the flow of water in rivers is regulated through the operation of major storages or weirs to secure water supplies. Unregulated systems have no major dams or weir structures, although they are still covered by licensing and trading frameworks governing the consumptive use of water. In this study, the ecosystem service of water provision is considered to be supplied when water yield flows into regulated water systems or unregulated systems that have sustainable diversion limits (SLDs). SLDs are used in this way as they provide an indication of systems where there is clear demand and consumptive use is actively managed. It should be recognised that consumptive use of water by households, businesses and government will be less than water provision from forests over a sufficient period of time, with the remaining quantity of water being an intermediate service to other ecosystem assets. This study has not matched water provision from forests into water supply systems with actual abstractions for consumptive use. This is a potential area for future work in Victoria which would add useful information to the analysis.

RFA regions have different profiles in terms of where water flows to from forests. Table 14 provides a snapshot of where water flows to in 2018, and Figure 16 provides a map of declared water systems across Victoria. The Central Highlands is the only RFA region that provides significant volumes of water to Melbourne’s system. It also provides significant volumes to the northern Victoria system, which supplies the Goulburn-Murray irrigation district. Around two-thirds of water from the North East RFA region goes to the northern Victoria system, and the remainder goes to unregulated systems. Around a quarter of water from the Gippsland RFA region also goes to the northern Victoria system, and around a third goes to the Thompson/Macalister irrigation district.

Table 14 Destination of water provision from forests (2018)

RFA region	Destination
Central Highlands	23% to Melbourne system 27% to northern Victoria system 10% to other regulated systems 40% to unregulated systems
East Gippsland	100% to unregulated systems
Gippsland	31% to Thompson/Macalister system 26% to northern Victoria system 43% to unregulated systems
North East	66% to northern Victoria system 34% to unregulated systems
West	4% to northern Victoria system 2% to Werribee system 16% to other regulated systems 77% to unregulated systems

Figure 16 Victorian declared water systems



Source: Victorian Water Register

Valuation of ecosystem service

Water provision can be valued using a market price approach and a replacement cost approach. Valuation is linked to the destination of water provision from forests (as shown in Table 14 and discussed above). When water is supplied to households and businesses by the water industry, the price of water is a combination of capital, labour and other inputs including the ecosystem service of water provision. For this reason, the market price of urban water supply to households and businesses is not used to value the ecosystem service. However, market prices (allocation prices) for rural water are used, as these prices more accurately reflect the value of the ecosystem service, isolated from other inputs such as capital and labour. This is because there are separate fees (known as delivery shares) that cover the costs of operating and maintaining channels, pipes and gates which deliver water.[53] As discussed previously, this study has not matched water provision into water supply systems with actual abstractions for consumptive use, which will vary from year to year and be less than water provision from forests over a sufficient time period. This is a potential area for future work in Victoria which would add useful information to the analysis.

A replacement cost approach is used to value water provision to Melbourne's system, and two options are applied as an upper and lower bound. The lower bound estimate is based on the cost of purchasing and transferring water to Melbourne from northern Victoria via a pipeline. The cost of transferring water to Melbourne includes the capital cost of pipeline infrastructure and the cost of pumping water. A capital cost of $100 per megalitre is derived from the North-South Pipeline, which transfers water from the Goulburn River to Melbourne's Sugarloaf Reservoir. The $750 million project can transfer over 75,000 megalitres of water per year.[54] Assuming linear depreciation and an asset life of 100 years, this equates to depreciation of $7.5 million per year and a capital cost of $100 per megalitre. The cost of pumping water to Melbourne has been estimated at $199 per megalitre,[55] bringing the cost of transferring water to Melbourne to $299 per megalitre (not including purchase of water). The cost of purchasing water (northern Victorian allocation price) is added to the cost of transfer to derive to total cost of providing water to Melbourne via transfer from another region. The upper bound estimate is based on the cost of supplying water to Melbourne via desalination. The cost of desalination was estimated at $1,370 per megalitre in 2009.[56] This approach is similar to that used by DELWP and Parks Victoria in 2015[57] and by Keith et al. in 2017.[58] Both studies used a replacement cost approach to value the ecosystem service of

53. Victorian Water Register 2019, 'About water entitlements: Delivery shares', accessed October 2019 at https://waterregister.vic.gov.au/water-entitlements/about-entitlements/delivery-shares
54. Productivity Commission 2011, *Australia's urban water sector – Final inquiry report*, report no. 55, Commonwealth of Australia, Canberra, p. 29.
55. Western, A, Taylor, N, Langford, J & Azmi, M 2017, *The economic value of water storage*, The University of Melbourne, Melbourne, p. 11.
56. Department of Treasury and Finance 2009, *Partnerships Victoria: Victorian desalination plant*, State of Victoria, Melbourne, p. 10.
57. Department of Environment, Land, Water and Planning & Parks Victoria 2015, Valuing Victoria's Parks: Accounting for ecosystems and valuing their benefits, State of Victoria, Melbourne.
58. Keith, H, Vardon, M, Stein, J, Stein J & Lindenmayer, D 2017a, Experimental ecosystem accounts for the Central Highlands of Victoria: Final report, Australian National University Fenner School of Environment and Society, Canberra; Keith, H, Vardon, M, Stein, J, Stein J & Lindenmayer, D 2017b, Experimental ecosystem accounts for the Central Highlands of Victoria: Appendices, Australian National University Fenner School of Environment and Society, Canberra.

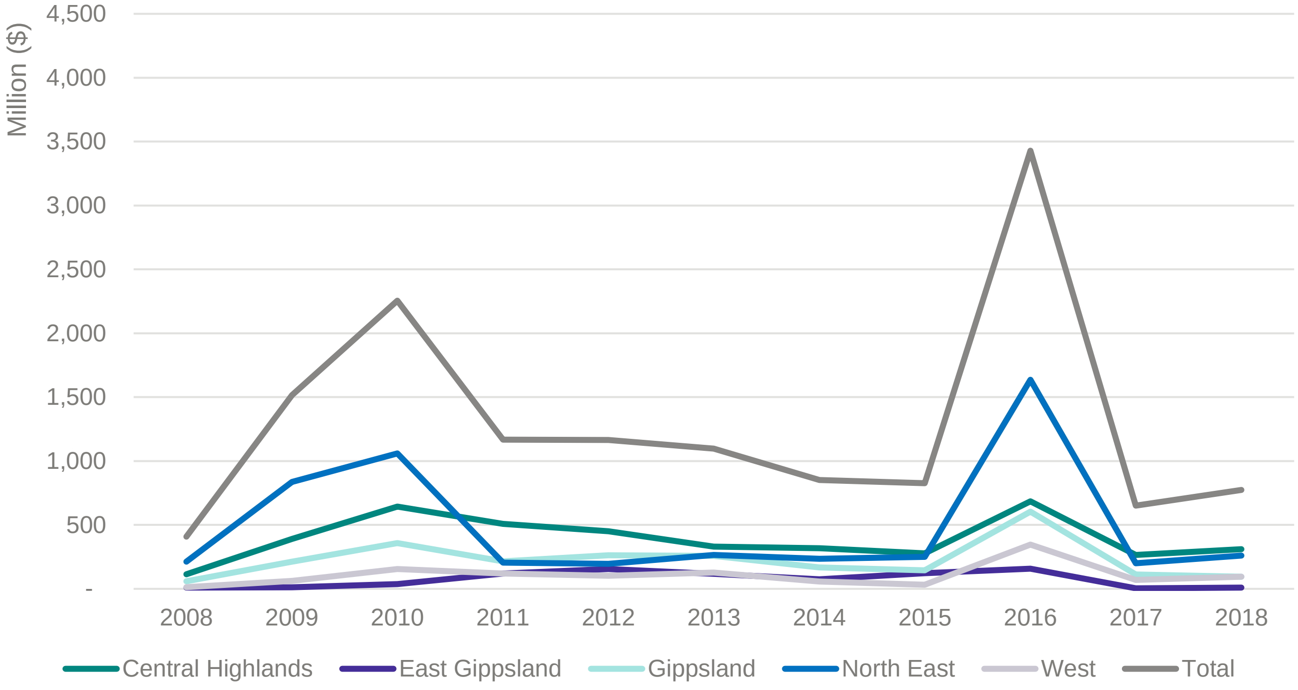
water provision to Melbourne, and applied two options based on the cost of water transfer and desalination.

For water provision to other systems, a market price approach is used based on the median price per megalitre of trade in allocated water in each declared system (northern Victoria, Thompson/Macalister and Werribee). For water yield to regulated systems that are not declared (where allocation trade does not occur), and to unregulated systems with sustainable diversion limits[59], median price per megalitre of trade in temporary take and use licenses is used. Unregulated systems with sustainable diversion limits are systems where there is no major infrastructure regulating the supply of water, but where take and use licenses can still be traded. Water yield to unregulated systems without sustainable diversion limits is not valued, as there is no trade and thus no suitable market price. This does not mean that this water has no value, but that valuation would require non-market valuation techniques that are beyond the scope of this study. These volumes are very small compared to total water provision from forests in RFA regions (less than 1 per cent).

Figure 17 shows the value of the ecosystem service of water provision from forests in RFA regions between 2008 and 2018. The underlying data is presented in Table 16 and represents lower bound estimates (as discussed above). Upper bound estimates are presented in Table 17. Fluctuations in the value of water provision from year to year are driven by changes in the quantity of water provision and changes in rural water prices. On average, the value of water provision is greatest for the North East RFA region, averaging $487 million per year from 2008 to 2018. This is largely due to the volume of water provision from forests in this region. Water provision from the Central Highlands RFA region also has a high value, averaging $390-1,091 million per year from 2008 to 2018. This reflects the significant volume of water provision from forests in this region, but also that around a quarter goes to Melbourne’s water supply system and has a high value.

59. Sustainable diversion limits (SLDs) provide an indication of the sustainable volume of water than can be diverted from a system without causing detrimental environmental impact. SDLs are used to determine upper limits on diversion from unregulated systems across Victoria.

Figure 17 Value of water provision from forests in RFA regions (2008–2018)



Note this figure shows lower bound estimates using replacement cost of water transfer to Melbourne via pipeline.

Table 15 Quantity of water provision from forests in RFA regions (megalitres)

RFA region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Central Highlands	413,093	1,358,060	3,544,452	3,825,370	3,450,629	2,458,901	2,238,798	1,511,839	2,998,349	2,262,309	1,747,530
East Gippsland	164,850	185,926	599,095	1,942,295	2,517,341	1,553,906	2,069,085	2,238,008	1,971,093	83,314	144,802
Gippsland	445,768	1,415,887	3,289,019	3,325,829	4,326,742	3,148,923	2,355,894	1,807,558	4,476,587	1,734,527	1,115,835
North East	946,653	3,667,191	8,627,465	5,125,182	5,442,416	4,744,181	3,869,636	2,597,293	9,424,965	4,112,990	2,414,068
West	126,075	656,450	1,576,012	1,321,060	1,186,659	1,581,770	900,693	434,486	2,474,916	1,255,449	1,009,526
Total	2,096,439	7,283,512	17,636,042	15,539,735	16,923,788	13,487,682	11,434,105	8,589,184	21,345,910	9,448,589	6,431,762

Table 16 Value of water provision from forests in RFA regions ($), using replacement cost of water transfer to Melbourne via pipeline

RFA region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Central Highlands	114,125,877	390,059,485	644,861,017	508,439,549	449,741,451	329,555,518	316,839,716	276,717,767	684,729,408	264,313,708	310,684,656
East Gippsland	10,248,618	11,602,332	37,222,159	120,259,134	155,849,155	116,447,540	75,782,505	123,042,625	157,735,578	4,154,583	10,863,553
Gippsland	59,070,224	213,656,158	358,052,240	215,522,615	262,441,368	258,012,436	168,496,227	143,865,181	604,186,400	112,747,747	94,915,355
North East	211,981,476	836,968,865	1,059,663,528	204,507,123	195,749,274	265,409,164	234,043,934	249,408,095	1,636,046,911	200,605,095	261,205,474
West	12,856,919	62,778,692	156,196,438	119,478,250	101,532,247	126,780,412	56,693,907	33,221,099	346,201,578	68,854,489	95,940,966
Total	408,283,114	1,515,065,532	2,255,995,383	1,168,206,671	1,165,313,495	1,096,205,069	851,856,289	826,254,767	3,428,899,875	650,675,621	773,610,005

Table 17 Value of water provision from forests in RFA regions ($), using replacement cost of water supply to Melbourne via desalination

RFA region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Central Highlands	200,287,269	751,887,417	1,599,098,292	1,778,967,065	1,611,185,417	1,124,719,564	1,012,757,696	774,930,922	1,371,276,397	971,214,369	805,842,231
East Gippsland	10,248,618	11,602,332	37,222,159	120,259,134	155,849,155	116,447,540	75,782,505	123,042,625	157,735,578	4,154,583	10,863,553
Gippsland	59,587,282	214,934,487	361,161,229	220,119,028	267,556,653	261,461,349	170,912,125	145,650,001	606,184,420	115,094,424	96,270,631
North East	211,981,476	836,968,865	1,059,663,528	204,507,123	195,749,274	265,409,164	234,043,934	249,408,095	1,636,046,911	200,605,095	261,205,474
West	12,857,123	62,778,841	156,198,591	119,478,922	101,532,317	126,783,061	56,693,907	33,221,118	346,203,770	68,854,499	95,941,280
Total	494,961,767	1,878,171,942	3,213,343,799	2,443,331,272	2,331,872,816	1,894,820,678	1,550,190,167	1,326,252,760	4,117,447,076	1,359,922,969	1,270,123,170

Biomass for timber

Description of ecosystem service and users

Forests in Victorian RFA regions provide biomass which is harvested for use in timber products. The direct user of this ecosystem service is the timber industry.

In Victoria, native timber harvesting takes place in areas of state forest that are available and suitable for timber harvesting. There are plantation forests on private and public land which also supply timber. VicForests is the state-owned business responsible for the harvest and sale of timber from state forests on behalf of the Victorian Government. VicForests also runs a small community forestry program in western Victoria. Plantations – which include hardwood and softwood – are owned and operated by investors, timber industry businesses, other private growers (including farm foresters[60]) and government.

Forests in Victoria provide three types of timber: sawlog, pulplog and other wood.[61] Sawlog is high quality timber from the lower to middle part of the tree trunk. Depending on its quality, sawlog can be used in products from pallets and roofing battens to furniture and flooring. Pulplog is from the branches and upper trunk and is primarily used to make paper and cardboard. A small amount of wood is used for other purposes such as firewood, posts and poles.

Quantification of ecosystem service

The ecosystem service of provision of biomass for timber is quantified as the volume of timber harvested from native and plantation forests across RFA regions.

Native timber

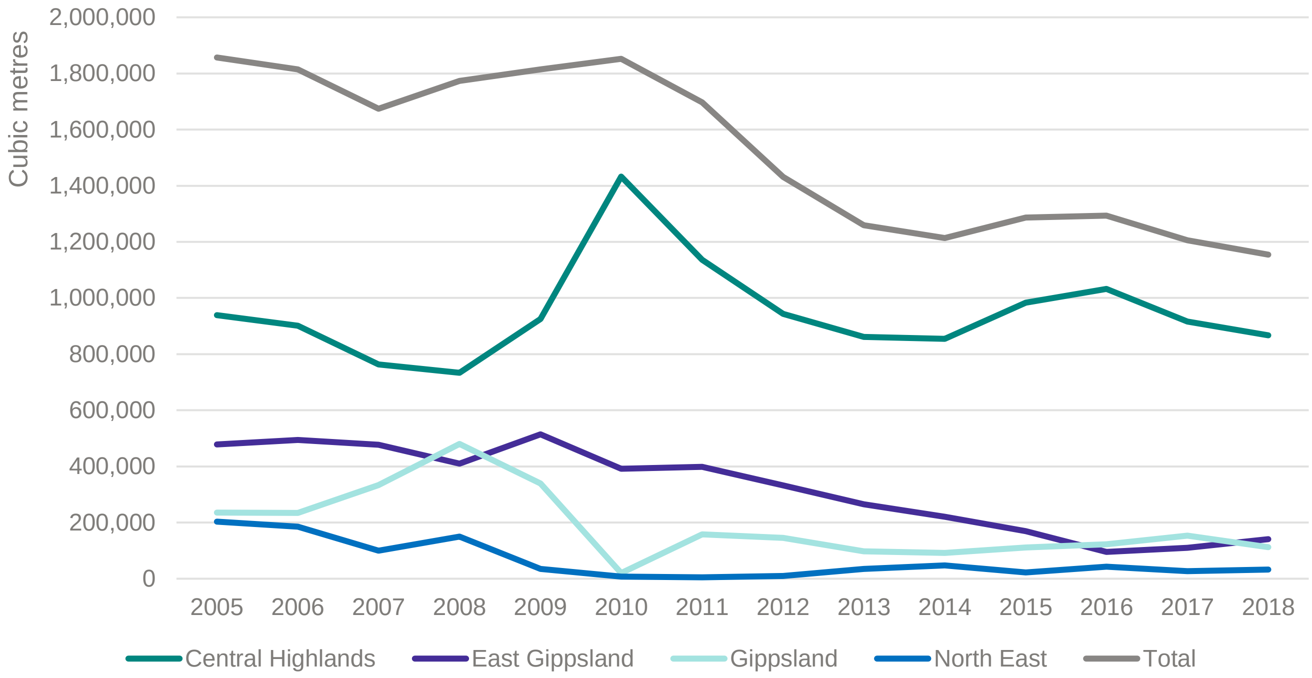
In 2018, VicForests harvested 1.2 million cubic metres of native timber across four RFA regions (Central Highlands, East Gippsland, Gippsland and the North East). The Central Highlands RFA region provided three quarters of native timber, followed by East Gippsland (12 per cent) and Gippsland (10 per cent). The North East RFA region provided just 3 per cent of native timber. Commercial native timber harvesting has not occurred in the West RFA region since 2008.

In 2018, almost 60 per cent of native timber harvested was ash species (mountain ash, alpine ash and/or shining gum[62]) with the remainder mixed species (other eucalypts). Almost half of all native timber harvested was ash species from the Central Highlands RFA region.

The volume of native timber harvested across the four RFA regions has decreased over time. Since 2005, total harvest volume has decreased by an average of 3 per cent per year, with the most significant decrease in the East Gippsland RFA region. Figure 18 shows the quantity of timber harvested from native forests in RFA regions between 2005 and 2018. The underlying data is provided in Table 19.

60. Farm forestry is the incorporation of commercial tree growing into farming systems such as cropping or livestock. It can take many forms, including timber belts, alleys and widespread tree plantings. Farm forestry plantations are typically of a smaller scale than industrial plantations.
61. Victorian Environmental Assessment Council 2017, *Fibre and wood supply: Assessment report*, State of Victoria, East Melbourne, p. 20.
62. Victorian Environmental Assessment Council 2017, *Fibre and wood supply: Assessment report*, State of Victoria, East Melbourne, p. 19.

Figure 18 Quantity of biomass for timber from native forests in RFA regions (2005–2018)



Note spikes in volume caused by salvage operations after bushfires in 2006 and 2009.
Source: VicForests

Plantation timber

Around 40 per cent of Victoria's plantations are hardwood and around 60 per cent are softwood.[63] Almost all plantations (over 99 per cent) are within RFA regions, with the greatest area in the West RFA region (59 per cent) followed by Gippsland (24 per cent) and the North East (13 per cent) – see Table 18. Plantations in the West RFA region are fairly evenly split between hardwood and softwood, whereas Gippsland plantations are around two thirds softwood, and North East plantations are almost all softwood.

In 2017-18, 7.8 million cubic metres of plantation timber was harvested in Victoria.[64] Forty-six per cent of this was hardwood and 54 per cent was softwood. The volume of plantation timber harvested from each RFA region is unknown. Roughly attributing volumes based on area of plantation in each region would suggest around 5 million cubic metres is provided from the West RFA region, around 2 million cubic metres from Gippsland, and around 1 million from the North East. However, without information on the maturity of plantations and expected harvest dates, it is difficult to accurately attribute an annual harvest volume to each region.

The volume of plantation timber harvested across Victoria has increased significantly over the past decade. Since 2007-08 total plantation harvest volume has grown by an average of 6 per cent per year. This has largely been driven by an increase in the volume of hardwood harvested. Figure 19 shows the

63. DELWP Corporate Spatial Data Library: Victorian plantation, VMVEG_plantation

64. Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), Australian forest and wood product statistics, accessed October 2019 at http://www.agriculture.gov.au/abares/forestsaustralia/australian-forest-and-wood-products-statistics

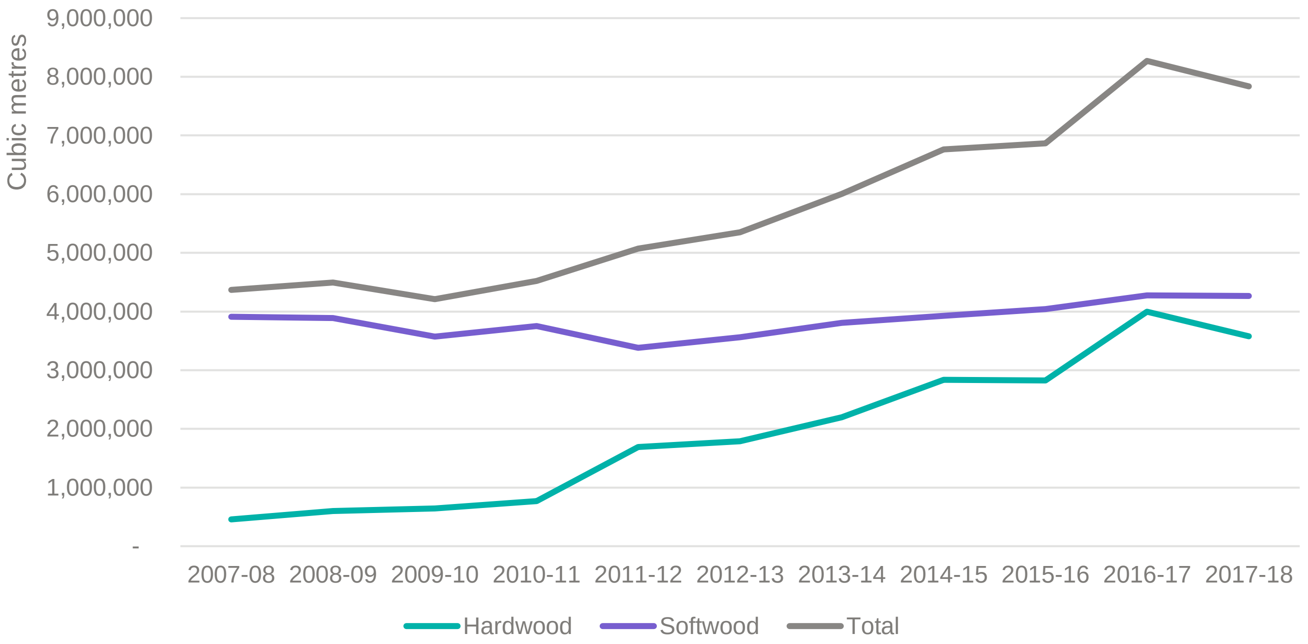
quantity of timber harvested from plantation forests in Victorian between 2007-08 and 2017-18. The underlying data is provided in Table 21.

Table 18 Area of plantation forests in RFA regions (hectares)

RFA region	Hardwood	Softwood	Total
Central Highlands	1,288	4,553	5,841
East Gippsland	2,735	-	2,735
Gippsland	20,948	45,506	66,454
North East	204	35,888	36,092
West	84,796	79,131	163,927
Total	109,971	165,078	275,049

Source: DELWP Corporate Spatial Data Library

Figure 19 Quantity of biomass for timber from plantation forests in Victoria (2007-08 to 2017-18)



Source: ABARES

Valuation of ecosystem service

The biomass provided by forest ecosystems has a value that is different to timber, as the market value of timber also includes inputs such as harvesting and haulage. Isolating the value of biomass reveals the contribution of the ecosystem.

Native timber

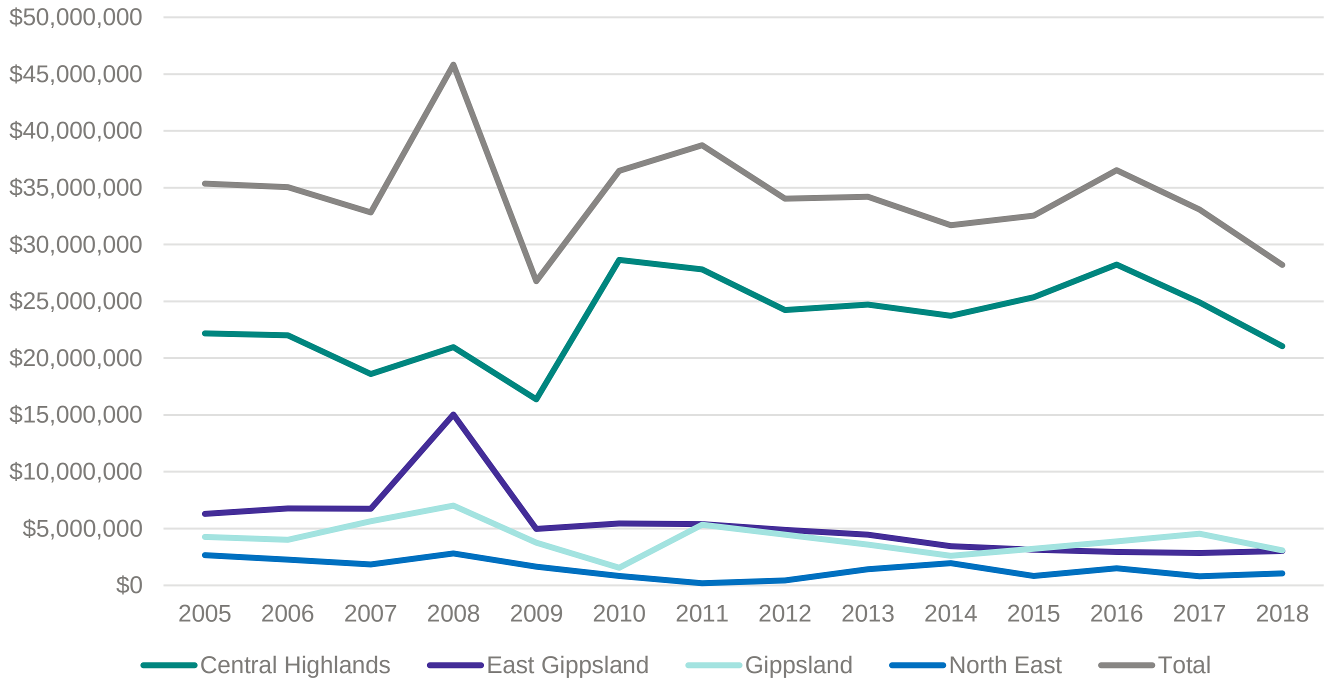
Provision of biomass from native forests can be valued using 'stumpage' revenue. This is a market price valuation technique, as stumpage revenue is the market value of timber less harvesting and haulage costs.

In 2018, stumpage revenue for native timber sales was $28.2 million across four RFA regions (Central Highlands, East Gippsland, Gippsland and North East), which equates to around $24 per cubic metre on average, although this varies across species, grade and region. The Central Highlands RFA region contributed around three quarters of stumpage revenue, followed by East Gippsland and Gippsland (both 11 per cent). This broadly aligns with the volume of timber harvested from each RFA region.[65]

In 2018, almost 70 per cent of stumpage revenue was from ash species, with the remainder from mixed species. The proportion of stumpage revenue that comes from ash is higher than the proportion of harvest volume that is ash. This is due to the higher value of ash logs compared to mixed species. In 2018, over 55 per cent of total stumpage revenue came from ash from the Central Highlands RFA region. Figure 20 shows the value of biomass for timber from native forests in RFA regions between 2005 and 2018. The underlying data is provided in Table 20.

65. Note that harvest volumes in a year may not align with sales volumes and therefore stumpage revenue in any year due to the influence of placing timber in storage for later sale.

Figure 20 Value of biomass for timber from native forests in RFA regions (2005–2018)



Note spikes in revenue caused by salvage operations after bushfires in 2006 and 2009.
Source: VicForests

Plantation timber

Information on plantation input costs is required to isolate and estimate the value contributed by the ecosystem. Studies have estimated that net expenditure (excluding within industry transfers) in the softwood and hardwood plantation industry (up to the point of primary processing) was $324 million in 2015-16 excluding the 'green triangle' region in southwest Victoria, and $116 million for the Victorian part of the green triangle region.[66] Subtracting this from the gross output value of plantation timber harvest for that year ($487 million, Table 22[67]) suggests that the value of the ecosystem service is around $7 per cubic metre, or $54 million in 2017-18.

66. Schirmer, J, Mylek, M, Magnusson, A, Yabsley, B & Morison, J 2017 *Socio-economic impacts of the forest industry – Green Triangle*, University of Canberra, Canberra, p. 12; Schirmer, J, Mylek, M, Magnusson, A, Yabsley, B & Morison, J 2018 *Socio-economic impacts of the forest industry – Victoria* (exc. the Green Triangle), University of Canberra, Canberra, p. 14.

67. Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), Australian forest and wood product statistics, accessed October 2019 at http://www.agriculture.gov.au/abares/forestsaustralia/australian-forest-and-wood-products-statistics

Table 19 Quantity of biomass for timber from native forests in RFA regions (cubic metres)

RFA region	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Central Highlands	939,381	900,900	763,653	733,656	925,577	1,432,530	1,136,227	943,543	861,591	854,128	983,562	1,032,187	916,162	867,488
East Gippsland	478,106	494,341	476,662	409,575	514,361	391,532	398,141	332,439	265,445	220,330	169,101	95,496	109,790	141,163
Gippsland	236,080	234,130	333,849	480,182	339,066	20,173	158,108	145,198	98,064	91,690	111,503	123,217	153,634	112,700
North East	203,267	185,505	100,008	150,031	35,434	8,033	4,977	10,233	34,620	47,603	22,044	42,460	26,460	33,114
Total	1,856,834	1,814,876	1,674,172	1,773,444	1,814,438	1,852,268	1,697,454	1,431,413	1,259,719	1,213,751	1,286,209	1,293,360	1,206,046	1,154,465

Source: VicForests

Table 20 Value of biomass for timber from native forests in RFA regions ($)

RFA region	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Central Highlands	22,168,285	22,016,363	18,589,393	20,964,048	16,374,694	28,646,745	27,812,902	24,228,432	24,717,863	23,724,231	25,368,387	28,239,664	24,910,152	21,043,987
East Gippsland	6,293,933	6,782,828	6,735,141	15,037,317	4,982,022	5,449,364	5,379,912	4,882,689	4,473,646	3,434,224	3,141,189	2,935,004	2,848,664	3,037,723
Gippsland	4,250,912	4,005,315	5,653,261	7,020,166	3,762,999	1,552,442	5,347,786	4,472,110	3,591,706	2,593,112	3,222,233	3,857,371	4,537,683	3,084,502
North East	2,651,856	2,253,292	1,852,347	2,809,209	1,653,629	841,360	187,026	446,702	1,408,649	1,950,499	816,234	1,503,475	786,453	1,046,897
Total	35,364,986	35,057,798	32,830,141	45,830,740	26,773,343	36,489,911	38,727,627	34,029,933	34,191,864	31,702,066	32,548,043	36,535,514	33,082,951	28,213,109

Source: VicForests

Table 21 Quantity of biomass for timber from plantation forests in Victoria (cubic metres)

		2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Hardwood	Sawlog	42,500	28,000	15,000	8,200	2,200	36,762	104,309	59,429	32,375	56,276	32,982
	Pulplog	414,333	572,909	625,646	759,613	1,687,240	1,752,519	2,095,197	2,774,827	2,794,822	3,940,174	3,544,230
	Other	-	-	-	-	-	-	-	-	-	-	-
	Total	456,833	600,909	640,646	767,813	1,689,440	1,789,281	2,199,506	2,834,256	2,827,198	3,996,450	3,577,212
Softwood	Sawlog	2,298,409	2,471,137	2,321,912	2,243,789	1,953,398	2,242,621	2,496,835	2,446,179	2,331,137	2,348,726	2,168,339
	Pulplog	1,535,710	1,312,545	1,172,146	1,433,215	1,360,615	1,244,147	1,223,256	1,414,622	1,629,184	1,853,622	2,014,549
	Other	77,246	106,597	75,507	74,923	67,198	72,862	85,824	67,289	79,247	72,057	79,028
	Total	3,911,365	3,890,280	3,569,565	3,751,927	3,381,211	3,559,630	3,805,916	3,928,089	4,039,568	4,274,405	4,261,916
Total	Sawlog	2,340,909	2,499,137	2,336,912	2,251,989	1,955,598	2,279,383	2,601,144	2,505,607	2,363,512	2,405,001	2,201,321
	Pulplog	1,950,043	1,885,454	1,797,792	2,192,828	3,047,855	2,996,667	3,318,453	4,189,449	4,424,006	5,793,796	5,558,779
	Other	77,246	106,597	75,507	74,923	67,198	72,862	85,824	67,289	79,247	72,057	79,028
	Total	4,368,198	4,491,188	4,210,211	4,519,740	5,070,651	5,348,912	6,005,421	6,762,345	6,866,766	8,270,855	7,839,128

Source: ABARES

Table 22 Output value of timber from plantation forests in Victoria ($)

	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Hardwood	29,170,335	42,936,152	46,790,595	56,970,754	107,008,870	111,758,100	151,112,164	195,759,604	194,317,090	297,741,047	29,170,335
Softwood	221,245,456	239,202,337	233,492,797	253,593,240	227,430,649	239,396,660	268,899,896	280,712,836	292,624,075	321,159,534	221,245,456
Total	250,415,791	282,138,490	280,283,392	310,563,994	334,439,519	351,154,761	420,012,060	476,472,439	486,941,165	618,900,581	250,415,791

Source: ABARES

Biomass for firewood

Description of ecosystem service and users

Forests in Victorian RFA regions provide biomass which is used for firewood. This ecosystem service is used by households who collect firewood directly from public or private land. Households benefit from using firewood for heating, cooking or aesthetic enjoyment. When firewood is commercially produced, the direct user of the ecosystem service is industry, rather than households. Commercial production is largely captured in the previous assessment of provision of biomass for timber, and this section specifically focuses on household collection.

In Victoria, firewood is provided directly to households from forests on public land, which is known as domestic firewood. Provision is constrained by domestic firewood collection policy and enforcement. Designated collection areas are managed by DELWP and Parks Victoria. There is an autumn collection season (1 April to 30 June) and a spring collection season (1 September to 30 November). A household is not allowed to collect more than 16 cubic metres a year, and a person is not allowed to collect more than 2 cubic metres in a day. It is illegal to sell wood from public collection areas or to use wood in a business. Some households would also collect firewood from forests on private land.

Firewood is also harvested from forests by industry who then supplies it to households and businesses, which is known as commercial firewood. Though not a primary purpose of its operations, a small proportion of timber harvested from native forests by VicForests is sold for use as firewood.[68] Firewood is also produced from plantations and farm forestry on private land.

Figure 21 outlines the different sources of domestic and commercial firewood from public and private land in Victoria. The sources that are available in a particular area varies across the state.

Figure 21 Sources of domestic and commercial firewood from public and private forests in Victoria

	Domestic firewood	Commercial firewood
Public forests	Fallen trees and branches due to natural causes By-product from DELWP and Parks Victoria forest and fire management operations, or from VicForests harvesting operations Collection alongside local municipal roads where permitted by councils	VicForests harvesting operations

68. VicForests 'Fact sheet: Commercial firewood sales', accessed October 2019 at http://www.vicforests.com.au/static/uploads/files/vicforests-firewood-fact-sheet-wfjpybkftntp.pdf

Private forests	Fallen trees and branches due to natural causes Tree cutting on private properties	Primary or by-product of plantations and farm forestry

In 2010, it was estimated that Victorians use about 600,000 cubic metres of firewood each year, with around 13 per cent coming from public land.[69] Significant volumes of firewood are thought to be obtained from private land in Victoria, either through household collection or commercial harvesting of plantations and farm forestry,[70] accounting for most of the remaining 87 per cent. Some firewood may also be obtained from interstate.

A typical household in Victoria that uses firewood for heating is estimated to consume between 1 and 9 cubic metres per year.[71] Slow burning, charcoal producing wood is often preferred for firewood (such as red gum, ironbark, and box species) over faster burning, ash producing wood (such as ash species).

Households benefit from using firewood for heating and cooking. Wood is the main source of heating for around 10 per cent of Victorian households and for around 25 per cent of regional households – see Table 23.[72] A smaller number of households also use wood for cooking and heating water. In 2008, around 4,700 households used wood for ovens and for heating water.[73]

Table 23 Victorian households that use wood as main source of heating (2014)

	Number of households	% of households
Regional	159,900	24.9
Melbourne	65,300	4.1
Total	228,100	10.2

Source: Australian Bureau of Statistics

Quantification of ecosystem service

The ecosystem service of provision of biomass for firewood is quantified as the volume of firewood collected or harvested from forests across RFA regions.

69. Department of Sustainability and Environment 2010, *Victoria's firewood strategy for public land*, State of Victoria, Melbourne, p. 1-3.
70. A survey of households conducted in 2000 found that around 45 per cent of firewood used by Victorian households was purchased and around 40 per cent was collected from private land. Driscoll, D, Milkovits, G, Freudenberger, D 2000, *Impact and use of firewood in Australia*, CSIRO Publishing.
71. Department of Sustainability and Environment 2010, *Victoria's firewood strategy for public land*, State of Victoria, Melbourne, p. 3.
72. Australian Bureau of Statistics Catalogue 4602.0.55.001 - Environmental Issues: Energy Use and Conservation, Mar 2014.
73. Australian Bureau of Statistics Catalogue 4602.0.55.001 - Environmental Issues: Energy Use and Conservation, Mar 2008.

Domestic firewood

It is estimated that a minimum of around 45,000 cubic metres of firewood is provided to the public from state forests across RFA regions each year.[74] The volume provided to the public includes firewood from natural falls, and by-product from DELWP forest and fire management operations or VicForests harvesting operations in some parts of the state.

The quantity of firewood collected for domestic use from forests on private land is unknown, though may be significant. A survey of firewood use in northern Victoria found that only 25 per cent of firewood dependent households collected firewood exclusively from public land.[75] It was estimated that around 14,000 cubic metres of firewood is provided annually from private property along the Murray River in Victoria and New South Wales.

Illegal removal of firewood

In Victoria, there are restrictions on the volume, location and type of wood that can be collected. Firewood is illegally removed from public land each year, with DELWP and Parks Victoria undertaking compliance activity. In an ecosystem accounting framework, illegal take could conceptually be included as an ecosystem service provided by forests, as it represents a flow from the ecosystem to people. However, the unsustainable removal of firewood results in degradation of the ecosystem asset (the forest).

Reducing unsustainable take (e.g. through rationing or enforcement) would reduce the flow of firewood from forests to the community and improve the condition of forests (the ecosystem asset). This may result in increased flows of other ecosystem services and benefits such as habitat for species, carbon storage or opportunities for recreation and tourism. It may also help maintain a flow of firewood into the future, rather than exhausting supply. Consequently, in some cases, reducing the flow of firewood may increase the overall benefit to the community from a forest. This is more likely to be the case in areas subject to intensive firewood collection (e.g. due to the type of wood, proximity to population centres, or where there are limited alternative collection areas nearby).

Commercial firewood

Some of the timber harvested by VicForests from state forests is sold and used for firewood, and the quantity and value of this is captured in the previous assessment of timber provision. Across the state, VicForests sold around 50,000 cubic metres of 'other' wood products in 2017-18, which is predominantly firewood.[76] To avoid double counting, these figures are not assessed again here.

The quantity of commercial firewood produced from plantations and farm forestry is unknown, though expected to be significant. This may also largely be captured in the previous assessment of timber provision.

74. Department of Environment, Land, Water and Planning, unpublished.

75. Department of Environment, Land, Water and Planning 2018, *Northern Victoria firewood and home heating project: Final recommendations*, State of Victoria, Melbourne.

76. VicForests 2018, *VicForests annual report 2017-18*, Melbourne, p. 13.

Valuation of ecosystem service

Provision of biomass for firewood can be valued using market prices. Market prices for firewood can vary widely depending on the type of wood and the location. Using regional market prices is appropriate for this analysis, as the main user of this ecosystem service is regional households who collect domestic firewood. In northern Victoria, firewood retails for around $100-160 per cubic metre (not including delivery).[77] This suggests that if households were to purchase firewood equivalent to the volume collected from public land, it would cost around $4.5–7.3 million.

Inputs to the provision of biomass for firewood from public land should be subtracted from the market price to isolate the value contributed by the forest ecosystem. Domestic firewood collection is subsidised by the Victorian Government which funds planning and administration of firewood collection areas. Costs have been estimated at around $12–43 per cubic metre for state forests.[78] Subtracting this from the market price gives a value of around $60–150 per cubic metre, or around $2.7–6.8 million in total. This represents the value of the ecosystem service of provision of biomass for firewood. Note that this is a conservative estimate as it does not include household collection of firewood from forests on private land.

77. Department of Environment, Land, Water and Planning 2018, *Northern Victoria firewood and home heating project: Final recommendations*, State of Victoria, Melbourne.

78. Department of Environment, Land, Water and Planning 2018, *Northern Victoria firewood and home heating project: Final recommendations*, State of Victoria, Melbourne.

Honey

Description of ecosystem service and users

Forests in Victorian RFA regions provide floral resources that support bee populations producing honey. The main user of this ecosystem service is the apiary industry which produces honey and other bee products. Households may also directly use this ecosystem service for non-commercial honey production. Forest areas also provide physical space to place artificial bee hives, including on public land.

Bees produce a range of products including honey, beeswax and royal jelly. Honey is the most common bee product in Victoria. Most Victorian honey is produced by European honeybees, although there is a small amount of production by native bees.

Honey production is heavily dependent on forest ecosystems for floral resources that sustain bee populations. Nationally, native flora has been estimated to support 70 to 80 per cent of honey production.[79] Eucalypts are by far the most important source of nectar and pollen.

In the absence of forests, other types of vegetation would provide some degree of substitution. However, given the reliance of bee populations on eucalypts, significant reductions in forest extent or access to forests would likely impact on honey production in Victoria. In response, consumers would reduce their consumption of honey and/or consume imported honey that is less preferred or higher cost.

Quantification of ecosystem service

Forests support the ecosystem service of honey provision by providing habitat and sustenance for bees. Honey production in Victoria is also dependent on policy settings which allow access to forests, and on human inputs to beekeeping such as capital and labour.

Habitat for bees

Forests provide habitat that supports bee populations. Forest ecosystem extent provides a broad indicator of provision of habitat for bees. The maintenance of forest ecosystem extent and condition is crucial to supporting bee populations, without which the ecosystem service of honey provision would decline.

Apiary sites

Honey production is highly dependent on human inputs such as capital and labour to deliver benefits to people. Although small quantities of wild honey would be obtained directly from forest ecosystems, most honey is produced in artificial beehives by industry or households.

There are 4,485 licensed apiary sites on public land across Victoria.[80] Fifty-five per cent of sites are in RFA regions, with the largest number in the West RFA region (22 per cent of total sites) followed by

79. Gibbs, D, & Muirhead, I 1998, *The economic value and environmental impact of the Australian beekeeping industry*, report prepared for the Australian beekeeping industry, p. 37.

80. Department of Environment, Land, Water and Planning dataset: Apiary rights and bee farm and range licenses.

Gippsland (13 per cent) – see Table 24. Figure 22 shows the location of apiary sites across RFA regions and non-RFA areas.

Apiary sites are typically located in and around forests. Figure 22 also shows forest extent across Victoria, illustrating a clear correlation. Sites outside of forest boundaries are typically positioned to ensure access to forest vegetation. The average distance of apiary sites from forest ranges from 0 metres in the Central Highlands RFA region (indicating that apiary sites are *within* forest areas) to 239 metres in the West. This is well within a bee's foraging distance.[81]

Although all apiary sites in this dataset are on public land, for a small number of these sites the nearest forest is on private land (see Table 26). This indicates that apiary sites on public land may be accessing floral resources on private land, and vice versa. Data on the number and location of hives on private land is not available. In 2001 it was estimated that 30 per cent of hives were located on private land.[82]

Apiary sites are not always licensed, and licensed sites may not always be occupied by hives. Occupation is dependent on nearby floral resources, which are seasonal and variable. Although occupation is sporadic, apiarists tend to retain sites to ensure access. A hive of bees may be moved several times a year.

Table 24 Apiary sites on public land by RFA region

Region	Sites	Percent of total sites (%)	Average distance from forest (m)[a]
Central Highlands	170	4	0
East Gippsland	349	8	5
Gippsland	586	13	26
North East	363	8	14
West	1,007	22	239
Non-RFA	2,010	45	287
Total RFA	2,475	55	-
Total Victoria	4,485	100	-

(a) A distance of 0 metres indicates that apiary sites are within forest areas.
Source: DELWP

Honey provision

A survey conducted by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) found that, in 2014-15, 58 per cent of honey produced in Victoria was derived from public land, with 40 per cent from state forests and 11 per cent from national parks.[83] Eight per cent was

81. The Victorian Government's *Apiculture (beekeeping) on public land standard operating procedure* suggests bee range diameter is 1.6 to 3.2 kilometres.
82. Centre for International Economics 2005 *Future directions for the Australian honeybee industry*, report prepared for the Department of Agriculture, Fisheries and Forestry, p. 141.
83. Australian Bureau of Agricultural and Resource Economics and Sciences 2016, *Australian honey bee industry: 2014-15 survey results*, Commonwealth of Australia, Canberra.

derived from other public land, 19 per cent from crops and 23 per cent from other private land (see Table 25).

This suggests that, at a minimum, 50 per cent of Victorian honey is derived from forests (state forests and parks). However, the proportion is likely higher because 'other public land' and 'other private land' would include areas of forest. For this analysis, an upper bound of 70 per cent is used. This assumes that all 'other public land' and half of 'other private land' is forest.

The ABARES survey found that there were 68,200 registered hives in Victoria, and estimated an average annual honey production of 59.4 kilograms per hive. This equates to total production of around 4,000 tonnes of honey per year. Earlier estimates of Victoria's honey production are of a similar magnitude. In 2015 it was estimated that Victoria produces around 4,250 tonnes of honey per year, around 17 per cent of Australia's honey production.[84] Applying the estimate that 50–70 per cent of Victorian honey is derived from forests suggests that 2,000 to 2,800 tonnes of honey can be attributed to forests. Based on the proportion of apiary sites in RFA regions (55 per cent), the volume derived from forests in RFA regions is around 1,000–1,500 tonnes per year.

Given the assumptions made around the use of apiary sites in RFA regions, confidence in the precision of this estimate is low, and it should be considered an indicative estimate only. For the same reason, the quantity of honey attributable to each RFA region cannot be estimated with confidence. However, the number of apiary sites in each RFA region (Table 24) is an indicator of access to floral resources, and suggests that the West and Gippsland RFA regions are particularly important areas for beekeeping.

Table 25 Proportion of honey produced in Victoria by land type (2014-15)

Land type	Proportion (%)
State forests	40
National parks	11
Other public land	8
Total public land	*58*
Crops (without paid pollination)	16
Crops (with paid pollination)	3
Other private land	23
Total private land	*42*

Source: ABARES

Valuation of ecosystem service

The ecosystem service of honey provision can be valued using market information reported in the ABARES survey. Analysis of survey data suggests that average cash receipts were around $6.30 per kilogram of honey and average cash costs were $3.40 per kilogram of honey in 2014-15. The difference is $2.90 per kilogram of honey, or $2,900 per tonne. Applying this to the volume of honey derived from

84. Department of Environment, Land, Water and Planning and Parks Victoria 2015, *Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne. p. 73; Department of Sustainability and Environment 2012, *Putting the buzz back in agriculture: Background issues paper*, State of Victoria, Melbourne.

forests in RFA regions suggests a total value of $3–4.5 million per year. This represents the value contributed by forest ecosystems.

Figure 22 Apiary sites and forest extent across RFA regions

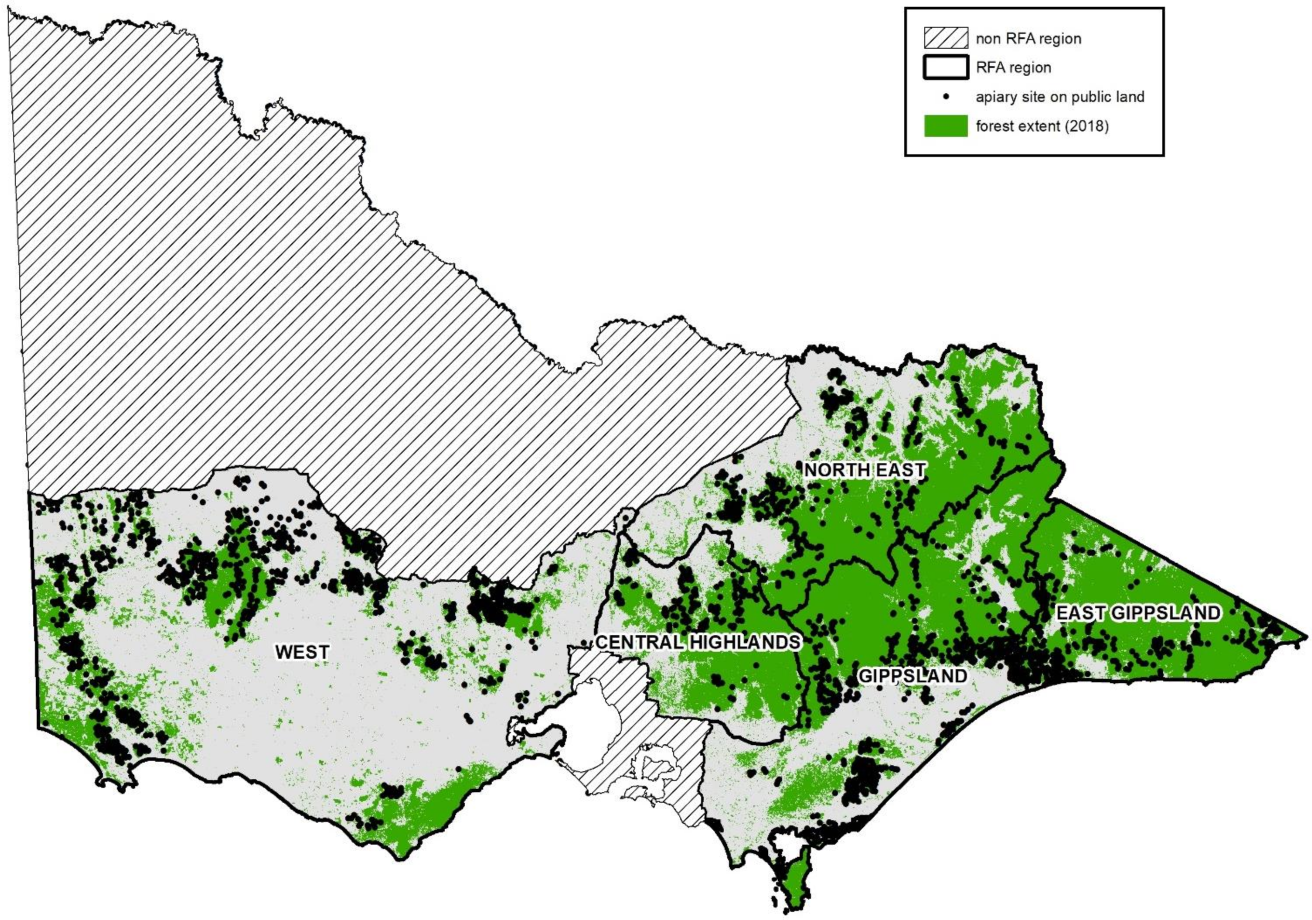


Table 26 Number of apiary sites and average distance to forest on public or private land or other vegetation on public land

	Central Highlands		East Gippsland		Gippsland		North East		West		Non-RFA	
	No. apiary sites	Average distance (m)	No. apiary sites	Average distance (m)	No. apiary sites	Average distance (m)	No. apiary sites	Average distance (m)	No. apiary sites	Average distance (m)	No. apiary sites	Average distance (m)
Private land forest (a)	*1*	*0.0*	*9*	*4.7*	*14*	*26.1*	*8*	*13.8*	*19*	*239.4*	*29*	*287.1*
Public land forest (b)												
State forest	153	0.2	254	0.9	413	1.0	265	0.4	588	5.9	582	11.9
Parks	15	0.0	69	1.1	94	9.7	62	1.1	314	5.2	1,022	18.4
Other conservation	0	-	10	0.0	24	75.6	12	3.7	40	110.6	210	40.8
Plantation	0	-	0	-	1	0.0	4	4.7	7	4.8	0	-
Commonwealth land	0	-	0	-	0	-	0	-	0	-	0	-
Other public land	1	0.0	6	0.7	7	58.3	11	3.4	27	74.5	33	31.0
Not classified	0	-	0	-	0	-	0	-	1	0.0	6	8.1
Total	*169*		*339*		*539*		*354*		*977*		*1,853*	
Public land other vegetation (c)												
State forest	0	-	1	0.0	5	3.0	0	-	0	-	35	39.9
Parks	0	-	0	-	26	7.9	1	0.0	4	78.0	76	60.7
Other conservation	0	-	0	-	1	1,284.1	0	-	0	-	14	213.0
Plantation	0	-	0	-	0	-	0	-	1	0.0	0	-
Commonwealth land	0	-	0	-	0	-	0	-	0	-	0	-
Other public land	0	-	0	-	1	2,891.8	0	-	2	0.0	3	273.7
Not classified	0	-	0	-	0	-	0	-	4	180.3	0	-
Total	*0*		*1*		*33*		*1*		*11*		*128*	
Total forest (a+b)	170		348		553		362		996		1,882	
Total public land (b+c)	169		340		572		355		988		1,981	
Total (a+b+c)	170	0.0	349	4.7	586	26.1	363	13.8	1,007	239.4	2,010	287.1

Fodder

Description of ecosystem service and users

Forests in Victorian RFA regions provide plant biomass (fodder) that is grazed by livestock. The user of this ecosystem service is the agriculture industry which uses fodder as an input to livestock production.

In Victoria, forests on private land and some areas of public forests can be used for grazing livestock. Forests provide space for livestock to move around and graze wild plants for nutrition and energy. Agricultural production from public forests is restricted by policy governing the use of public land.

Quantification of ecosystem service

Ideally, this service would be measured as the quantity of fodder consumed by grazing livestock. That is, the quantity of plant biomass provided by forest ecosystems from grazing. However, this data is not available and cannot be reliably estimated for Victorian forests.

In the absence of information on the quantity of fodder, opportunities for agricultural use of forests on public land has been mapped using spatial data on licenses for private use of public land.[85] This provides an indication of areas of forest that may provide fodder for grazing livestock. Key types of licenses that intersect with forest extent and may support agricultural production are:

- Grazing licenses – allowing grazing of livestock on public land.
- Water frontage and riparian management licenses – allowing access to waterways for agricultural use (such as stock access to water) or recreational use. Riparian management licenses ensure waterway access is managed to both protect and improve the riparian environment, and typically attract a reduced license fee.
- Unused roads licenses – allowing owner/occupiers of adjoining private land to access unused roads on public land for agricultural purposes.

Each licence is a distinct area of land: multiple licenses cannot cover the same area of land. There are around 14,100 licenses that intersect with forests in RFA regions (see Table 27). These licenses cover almost 500,000 hectares of forest, or 8 per cent of total forest in RFA regions. Most of this is grazing licenses (89 per cent of total forest area licensed), with smaller areas licensed for unused road access, water frontage access and riparian management and other uses.

The Gippsland RFA region has the largest area of forest covered by licenses (301,147 hectares). The West RFA region has the greatest number of licenses that intersect with forests (4,950), although the area of forest covered by licenses is quite low (10,980 hectares). This is likely due to the West RFA region having a large number of unused road licences that intersect with forest extent. Grazing licenses represent large portions of the total forest areas licensed in the Gippsland, East Gippsland and North East RFA regions (see Figure 23).

It should be noted that the number of licenses and area licensed is an indicator of *opportunity* for use of public forests for agricultural production. It is does not show whether forests are actually being used for grazing or other agricultural purposes.

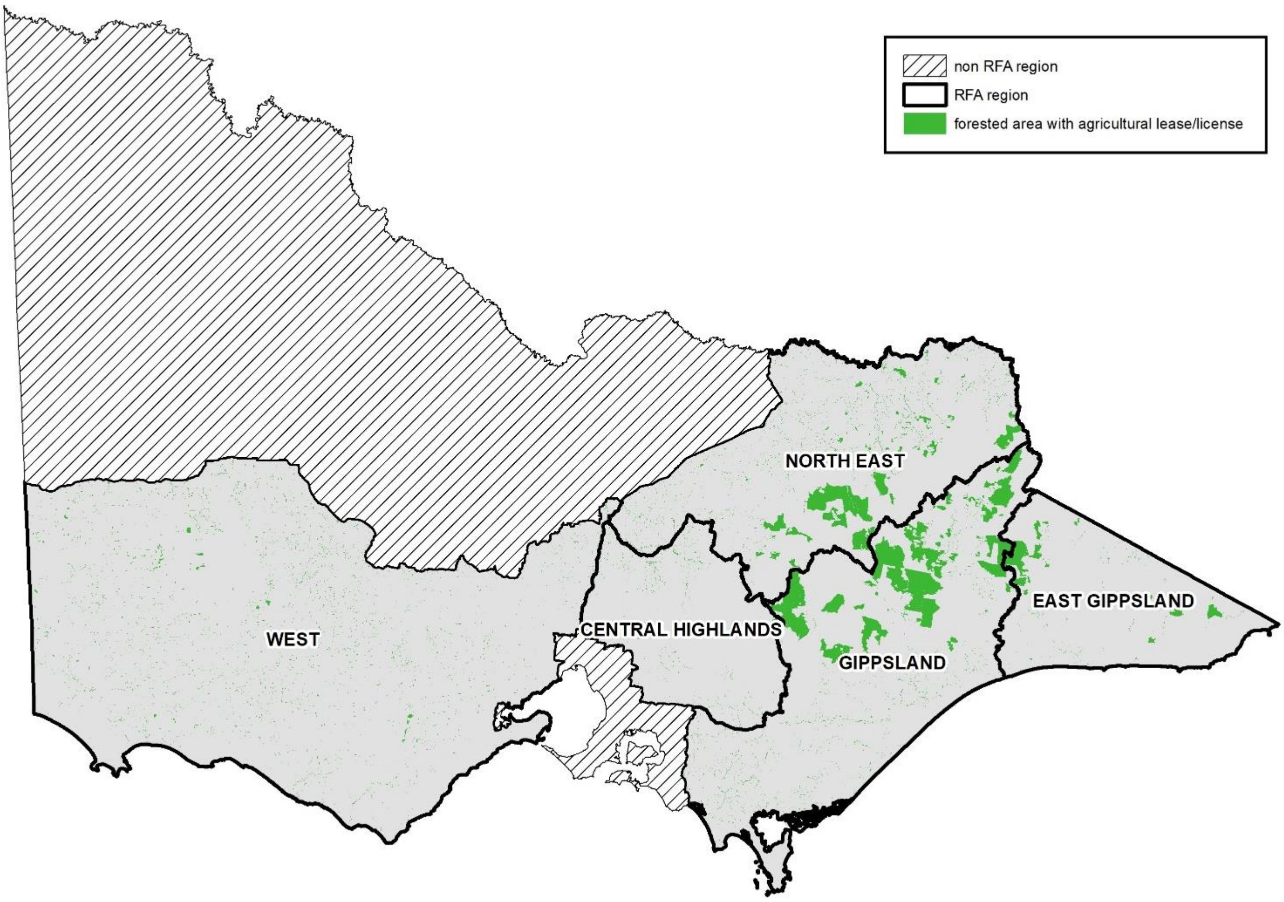
85. Department of Environment, Land, Water and Planning dataset: Crown land tenure - general licences.

Table 27 Agricultural licenses that intersect with forest areas

RFA region	Number of licenses	Area of forest licensed (hectares)
Central Highlands	1,728	5,783
East Gippsland	630	44,354
Gippsland	2,756	301,147
North East	4,067	132,126
West	4,950	10,980
Total	14,131	494,391

Includes grazing licenses, water frontage and riparian management licences, unused road licenses and miscellaneous licenses that intersect with forest extent.
Source: DELWP

Figure 23 Victorian agricultural licenses that intersect with forest areas



Regulating services

Water flow regulation

Description of ecosystem service and users

Forests in Victorian RFA regions regulate the flow of water which helps to mitigate the impact of flood events. Forest ecosystems store, transpire and redirect water from rainfall, both reducing and retarding peak runoff events to river systems.[86] This ecosystem service is used by households, industries and government who benefit from reduced occurrence and/or severity of river flooding.

Quantification of ecosystem service

A counterfactual scenario is constructed to assess the reduction in water yield that can be attributed to forests. Two options are modelled: one that replaces all forest cover with pasture, and one that replaces all forest cover with bare earth. These counterfactual scenarios are modelled from 2008 to 2018 using BioSim, alongside the same current forest extent scenario used to assess the ecosystem service of water provision.

The pasture scenario is a similar approach to that used in 2015 to assess water-related services provided by Victoria's parks.[87] The bare earth scenario has been used in this study as it reflects emerging consensus in ecosystem accounting that ecosystem services should be assessed against a counterfactual of no vegetation cover, or bare earth.[88] Pasture, for example, is simply another type of ecosystem.

Under the pasture scenario, water yield increases by an average of 8,909 gigalitres per year, compared to the current forest extent scenario. While under the bare earth scenario, water yield increases by an average of 16,101 gigalitres per year, compared to the current forest extent scenario.

Figure 25 and Figure 26 show the increase in average annual water yield that would occur across RFA regions under the pasture and bare scenario respectively, compared to the current forest extent scenario. This simply shows the reduction in water yield that can be attributed to forests across RFA regions. How this translates into stream flow and occurrence of flood events depends on a complex set of factors.

Spatial analysis was undertaken to identify the users, or beneficiaries, of the water flow regulation service provided by forests. Victoria is divided into a total of 2,973 localities[89] and 770 have residential, commercial or industrial areas[90] within the 1 in 100-year flood zone.[91] Of these, 646 localities have RFA forest in their upstream catchment (even if the locality itself is not in an RFA region, see Figure 24). The combination of a locality being in the 1 in 100-year flood zone and having RFA forest in its catchment is

86. Crossman, N, Nedkov, S, Brander, L 2019, *Discussion paper 7: Water flow regulation for mitigating river and coastal flooding*, paper submitted to the Expert Meeting on Advancing the Measurement of Ecosystem Services for Ecosystem Accounting, New York 22-24 January 2019 and subsequently revised, version of 1 April 2019, p. 4.

87. Department of Environment, Land, Water and Planning and Parks Victoria 2015, *Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne.

88. For example see discussion in Harris, R, Portela, R, Alam, M, Dvarskas, A, Ometto Bezerra, M, Hein, L, Chaplin-Kramer, B, Burkhard, B, Crossman, N, Obst, C & Barton, DN 2019, *Ecosystem services cross-cutting issues: Summary paper*, prepared for the 2019 Forum of Experts in SEEA Experimental Ecosystem Accounting, 26-27 June 2019, Glen Cove, New York, version of 14 June 2019.

89. A locality is a statewide standardised boundary registered by the Registrar of Geographic Names. In urban areas locality is analogous to suburb.

90 As defined by VLUIS land use mapping.

91. The 1 in 100 year flood zone delineates modelled statistical flood extents with an average recurrence interval (ARI) of 100 years, for further information see https://discover.data.vic.gov.au/dataset/1-in-100-year-flood-extent

used as an indicator of receipt of water flow regulation services. This analysis suggests that forests in RFA regions are providing some level of water flow regulation services to 646 localities across Victoria, including many localities in metropolitan Melbourne. Combined, these 646 localities have 13,596 hectares of urban, commercial and industrial land within the 1 in 100-year flood zone. Table 28 shows the number of localities that forests in each RFA region provide water flow regulation services to. The number of localities sums to more than 646 as some localities receive services from multiple RFA regions. Forests in the West RFA region provide water flow regulation services to the greatest number of localities (347 localities), followed by Gippsland (195 localities).

For each locality, the proportion of upstream catchment that is RFA forest provides an indication of the level of water flow regulation services being provided. That is, localities that have a high proportion of RFA forest in their catchment (compared to other land cover or non-RFA forest) are receiving a greater quantity of water flow regulation services from RFA forests. Table 29 shows the number of localities that have different proportions of RFA forest within their catchment. For example, 120 localities have RFA forest in 10–19 percent of their catchment, while 53 localities have RFA forest in 90–99 per cent of their catchment. The table also shows corresponding area of urban, commercial and industrial land within the 1 in 100-year flood zone. This provides a relative indication of the area of land receiving benefits from water flow regulation services.

It should be noted that this assessment provides a conservative indication of areas benefiting from water flow regulation services, as it only considers localities with urban, commercial or industrial land. Agricultural areas would also benefit significantly from water flow regulation services provided by forests.

Table 28 Number of localities receiving water flow regulation services from forests in RFA regions

RFA region	Number of localities
Central Highlands	142
East Gippsland	57
Gippsland	195
North East	183
West	347

Note that the number of localities sums to more than 646 as some localities receive services from multiple RFA regions

Table 29 Proportion of RFA forest in the catchment of localities receiving water flow regulation services

% of catchment that is RFA forest	Number of localities	Area of urban, commercial and industrial land within 1 in 100-year flood zone (ha)
0–9	122	3,053
10–19	120	3,332
20–29	69	615
30–39	47	1,802
40–49	57	1,413

50–59	57	986
60–69	40	522
70–79	34	477
80–89	47	911
90–99	53	485
Total	646	13,596

Valuation of ecosystem service

The contribution of water flow regulation to flood mitigation benefits can be valued based on the damage costs that would be incurred in the absence of forests, or the cost of mitigating floods through artificial means such as levees. Damage costs are very location specific and depend on the infrastructure, industries and population that would be impacted by flooding. Damage costs in areas with low population density and fewer industries and infrastructure are typically lower than in densely populated urban areas or areas of significant industrial activity and agricultural production.

A case study of Wangaratta has been undertaken to estimate the avoided damage costs due to forests in the catchment. This case study is then extrapolated out to localities across Victoria (those identified in Table 29 and Figure 24) to provide an indicative estimate of the broader value of water flow regulation services provided by forests in RFA regions. It should be noted that the statewide estimate is based on top-down extrapolation rather than bottom up hydrological modelling. Therefore, it should be considered an initial, indicative estimate only. However, it is likely a conservative estimate as it is based on damage costs to infrastructure and property. It does not consider broader impacts on productivity or human lives.

Case study of water flow regulation service provided by forests to Wangaratta

A case study has been undertaken for the town of Wangaratta in north east Victoria. Water yield in the Ovens catchment is modelled using BioSim from 2008 to 2018 under a forest scenario and a pasture scenario.[92,93]

Figure 27 shows average annual water yield upstream of Wangaratta under the forest scenario, while Figure 28 shows the average annual increase in water yield under the pasture scenario (compared to the forest scenario), ranging from 0 megalitres per hectare per year to more than 2.5 megalitres per hectare per year in some parts of the catchment.

The flow of water (megalitres per day) in the Ovens River at Wangaratta is modelled and the difference between the two scenarios is converted to an increase or decrease in daily river height and added to actual recorded river gauge data from 2008 to 2018. This allows actual recorded data on river height to be compared with estimated river height under the pasture scenario. The modelled stream flow volumes are calculated using gross catchment water yield with no river system delivery modelling. The exact timing of peak flows could be improved by linking BioSim water yield outputs with a river delivery model.

The number of days per year that the Ovens River at Wangaratta reaches a certain height is presented in Table 30. These heights have been selected as they are expected river heights for average

92. Note that a counterfactual where forest cover is replaced with bare earth is not used for this case study due to EnSym being unable to generate daily output data when there is no plant/crop.

93. For this Wangaratta scenario catchment water yield comprises modelled surface runoff and sub-surface lateral flow, groundwater recharge is not included. For further discussion refer to Appendix D.

recurrence interval (ARI) events (once in 5, 10, 20, 50, 100 and 200-year rainfall events) under current conditions.

Table 31 presents similar information, reporting the number of days per year that the Ovens River at Wangaratta reaches a certain height that corresponds with flood classes (minor, moderate and major). Between 2008 and 2018 the Ovens River reached minor flood levels on 65 days according to actual recorded data, increasing to 78 days under the pasture scenario. The number of days it reaches moderate flood levels triples under the pasture scenario, increasing from 15 to 43. The number of days it reaches major flood levels more than doubles, increasing from 4 to 9.

The BioSim model calculates gross catchment water yield without modelling any instream dynamics, meaning that the timing of peak flows will not always be accurate. Additionally, the calculation of river stage heights from modelled flow volumes requires the use of a rating curve which can add small errors to river stage heights. These issues combined can result in less flood events under the pasture scenario, such as the number of minor flood days in 2016. In these instances, the total flow volume for the flood event would still be larger in the pasture scenario, but without the same peak flow. This could be improved by incorporating BioSim with a dynamic in-stream model.

As previously discussed, flood control services provided by forests can be valued using an avoided damage cost approach. Damage cost estimates for Wangaratta are available from a 2017 study by the North East Catchment Management Authority (see Table 32).[94] The study estimates flood damage costs for Wangaratta at different river heights. Estimates include the cost of damage to residential and commercial buildings, as well as the cost of external damage to properties and public infrastructure. Estimates range from $1.6 million for a river height of 12.50 metres to $8.6 million for a river height of 13.03 metres.

These damage cost estimates are applied to the number of flood events at different river heights for the actual recorded data and for the pasture scenario. For example, in 2010 under actual recorded data, the river reaches a maximum height between 12.71 and 12.82 metres in two separate flood events, associated with an estimated damage cost of $5.5 million. Whereas under the pasture scenario, there are three separate flood events with the river reaching between 12.50 and 12.62 metres, between 12.82 and 12.92 metres, and over 13.03 metres, associated with an estimated damage cost of $14.8 million. The difference in damage costs between the two scenarios is $9.3 million. Applying this approach to each year results in additional damage costs of $52.7 million between 2008 and 2018 under the pasture scenario, or an average of $4.8 million per year. This is an estimate of the annual value of flood control services provided by forests to Wangaratta.

This approach does not account for any damage costs that may also be incurred below a river height of 12.50 metres. It also assumes that damage costs are incurred each time a separate flood event occurs (defined as at least two weeks between floods). In reality, recovery may not be completed before the next flood event occurs, meaning that the full damage costs may not be incurred again. (Although separate flood events in close succession may delay recovery and exacerbate damage costs.) This

94. Water Technology 2017, *Wangaratta urban waterways flood investigation: Study report*, report prepared for the North East Catchment Management Authority.

approach also assumes no behavioural response where households or businesses move from flood prone areas.

This analysis likely gives a conservative estimate of the value of the water flow regulation service forests provide to Wangaratta, as it only accounts for the tangible costs of damage to property and infrastructure. It does not account for disruption and productivity losses or intangible costs such as deaths, injuries and impacts on health and wellbeing. In 2017, Deloitte estimated that in Australia the intangible costs of floods can be 2.17 times the tangible costs.[95]

Extrapolation of case study to the whole of Victoria

The Wangaratta case study has been extrapolated out to localities across Victoria to provide an indicative estimate of the broader value of water flow regulation services provided by forests in RFA regions. It should be noted that this statewide estimate is based on top-down extrapolation rather than bottom up hydrological modelling. Therefore, it should be considered an initial, indicative estimate only. However, it is likely a conservative estimate as it is based only on tangible costs of damage to property and infrastructure in towns. It does not consider impacts on non-urban areas, productivity, or human life and health.

The extrapolation draws on spatial analysis undertaken to identify the number of localities that have urban, commercial or industrial land within the 1 in 100-year flood zone *and* have RFA forest in their catchment (see Table 29). A linear relationship between the damage costs per hectare of land within the 1 in 100-year flood zone and the proportion of catchment that is forest is derived based on the Wangaratta case study.

Damage costs are then applied to other localities across Victoria based on the area of land within the 1 in 100-year flood zone and the proportion of each locality's catchment that is RFA forest. This results in an estimated damage cost of $97 million per year across Victoria.

Key limitations of this extrapolation are that it assumes a linear increase/decrease in damage costs per hectare of land within the 1 in 100-year flood zone relative to the proportion of the catchment that is forest, and that damage costs in other localities are the same as Wangaratta on a per hectare basis. Biophysical limitations include extrapolating the number and magnitude of flood events from Wangaratta to the rest of the state, however this will be partly mitigated by using the 1 in 100-year flood extents particular to each locality. This assessment also assumes flood waters impacting on a location are always derived from its upstream contributing area, this isn't always the case, particularly in riverine flood events where water can back up or flow into adjacent waterways.

95. Deloitte 2017, *Building resilience to natural disasters in our states and territories*, report prepared for the Australian Business Roundtable for Disaster Resilience and Safer Communities, p. 107.

Figure 24 Victorian localities benefiting from water flow regulation services provided by forests in RFA regions

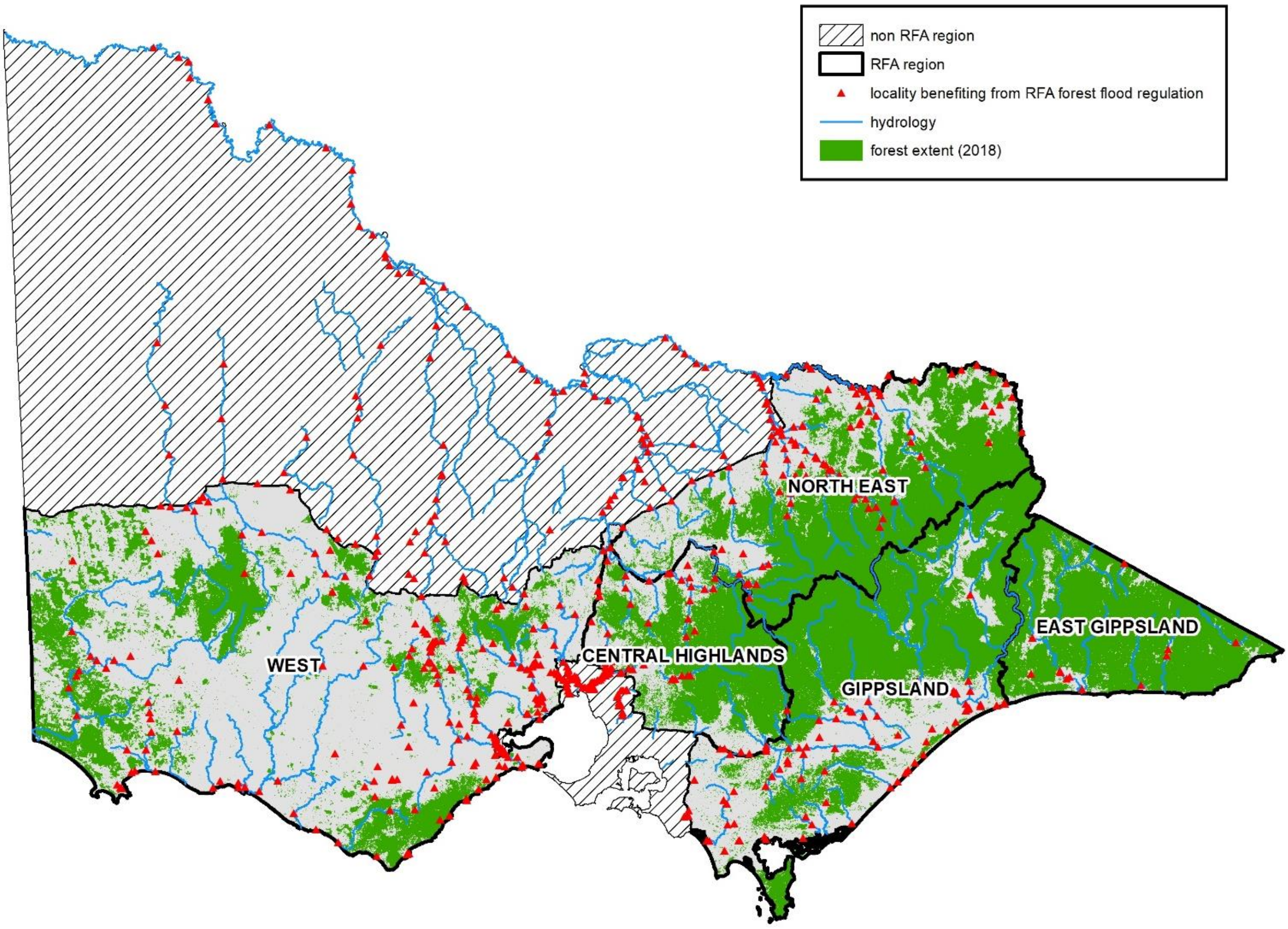


Figure 25 Increase in average annual water yield under a pasture scenario, compared to the forest scenario (2008–2018)

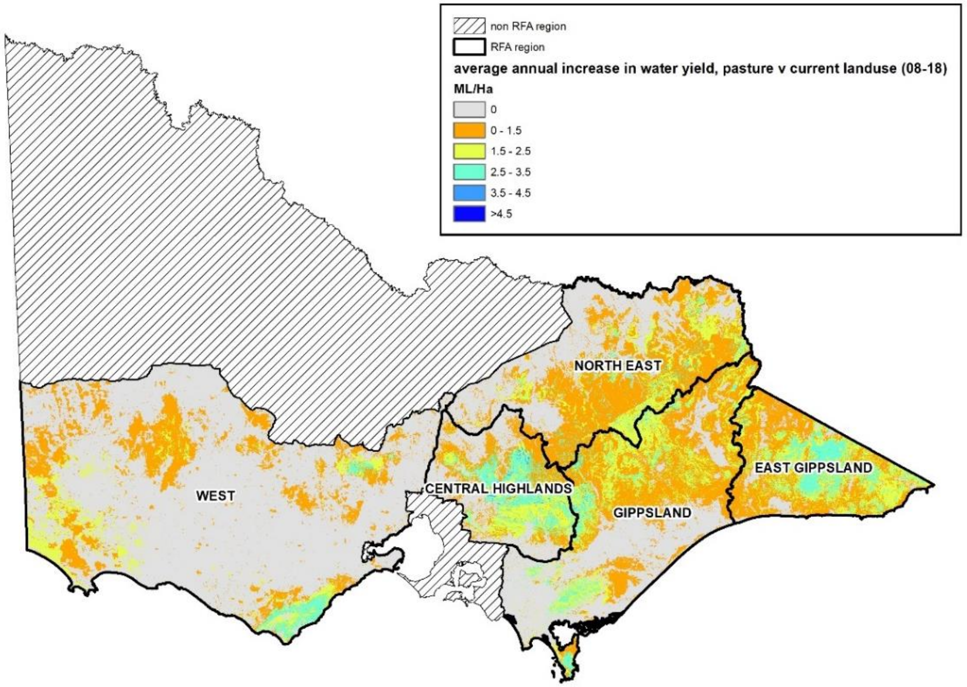


Figure 26 Increase in average annual water yield under a bare earth scenario, compared to the forest scenario (2008–2018)

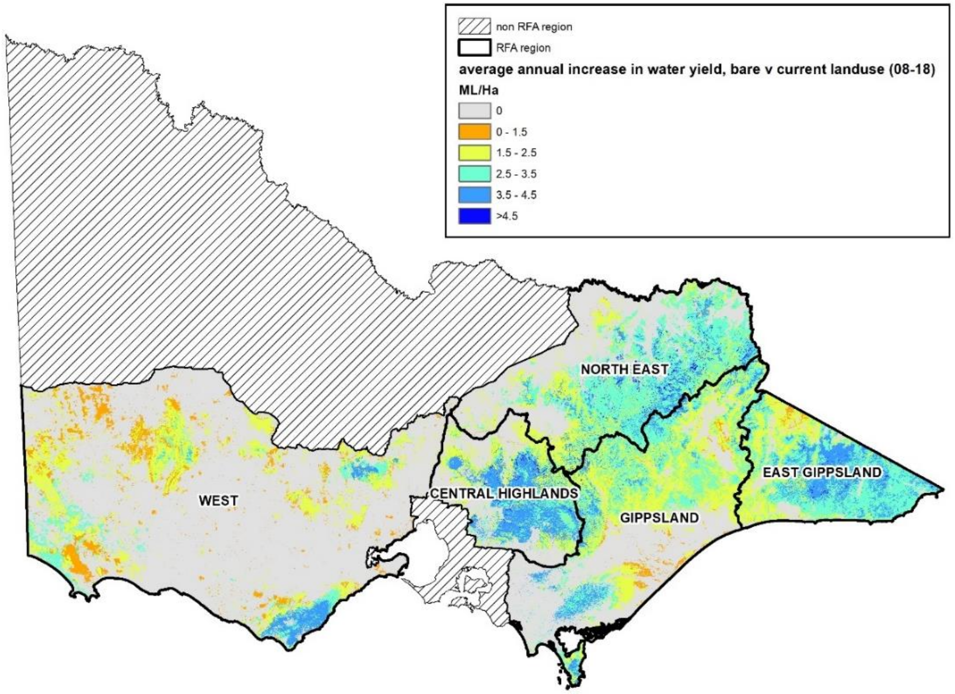


Figure 27 Total average annual water yield in the Ovens catchment upstream of Wangaratta under the forest scenario (2008–2018)

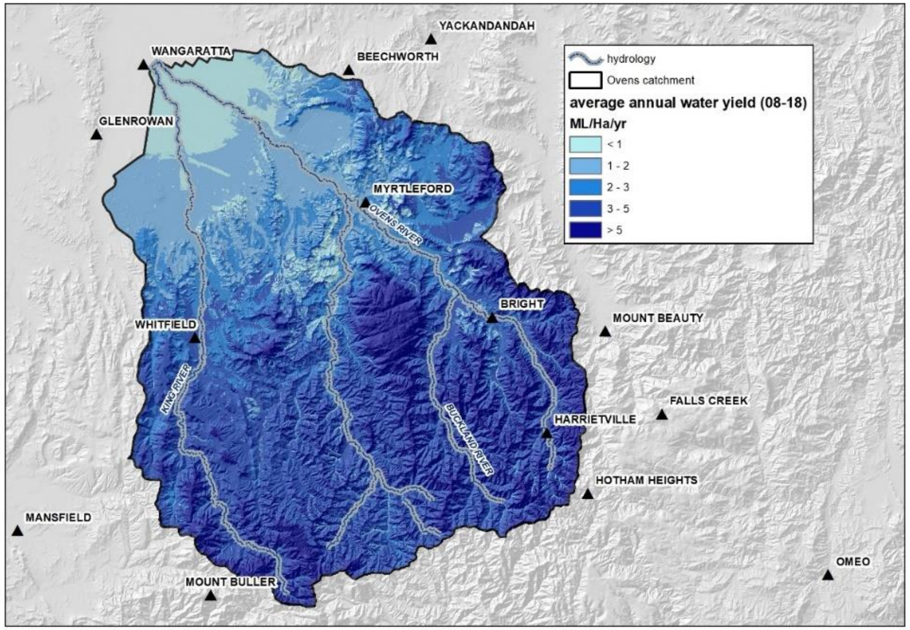


Figure 28 Increase in average annual water yield in the Ovens catchment upstream of Wangaratta under a pasture scenario, compared to the forest scenario (2008–2018)

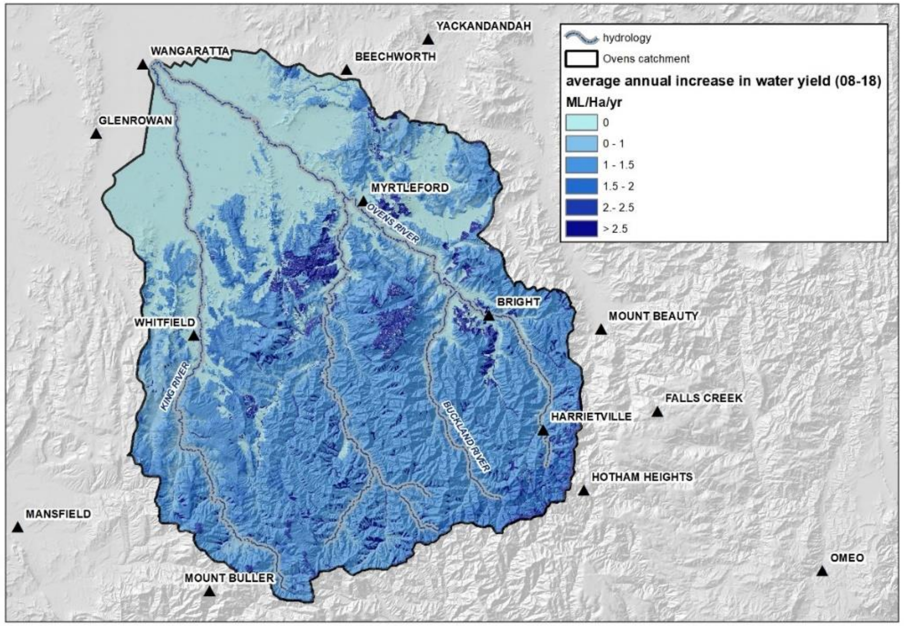


Table 30 Number of days Ovens River at Wangaratta reaches gauge levels and corresponding average recurrence interval (ARI)

	Forest scenario[a]						Pasture scenario					
ARI	*5*	*10*	*20*	*50*	*100*	*200*	*5*	*10*	*20*	*50*	*100*	*200*
Level (m)	*12.50*	*12.62*	*12.71*	*12.82*	*12.92*	*13.03*	*12.50*	*12.62*	*12.71*	*12.82*	*12.92*	*13.03*
2008	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	1	-	-	-	-	-
2010	2	1	2	-	-	-	5	1	-	1	-	1
2011	-	-	-	-	-	-	2	-	-	-	-	1
2012	-	-	-	-	-	-	5	-	-	-	-	2
2013	-	-	-	-	-	-	-	-	-	-	-	-
2014	-	-	-	-	-	-	-	-	-	-	-	-
2015	-	-	-	-	-	-	1	-	-	-	-	-
2016	5	2	1	-	-	-	5	-	-	-	-	-
2017	-	-	-	-	-	-	2	-	-	-	-	1
2018	-	-	-	-	-	-	2	-	2	-	1	-
Total	7	3	3	-	-	-	23	1	2	1	1	5

(a) Actual recorded stream flow data.

Table 31 Number of days Ovens River at Wangaratta reaches gauge levels and corresponding flood class

	Forest scenario[a]			No forest scenario		
Flood class	*Minor*	*Moderate*	*Major*	*Minor*	*Moderate*	*Major*
Level (m)	*11.90*	*12.40*	*12.70*	*11.90*	*12.40*	*12.70*
2008	-	-	-	-	-	-
2009	-	-	-	1	1	-
2010	9	4	3	18	7	2
2011	7	-	-	11	6	1
2012	8	1	-	9	8	2
2013	10	-	-	9	2	-
2014	1	-	-	2	-	-
2015	-	-	-	-	1	-
2016	26	10	1	20	14	-
2017	4	-	-	8	2	1
2018	-	-	-	-	2	3
Total	65	15	4	78	43	9

(a) Actual recorded stream flow data.

Minor flooding: causes inconvenience. Low-lying areas next to watercourses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.

Moderate flooding: In addition to the above, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required.

Major flooding: In addition to the above, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood affected areas may be required. Utility services may be impacted.

Table 32 Ovens River at Wangaratta – gauge level and corresponding flood class, ARI and estimated damage cost

Gauge level (metres)	Flood class level	Average recurrent interval (ARI)	Estimated damage cost
11.90	Minor		
12.40	Moderate		
12.50		Once in 5 years	$1,630,106
12.62		Once in 10 years	$2,160,821
12.70	Major		
12.71		Once in 20 years	$2,751,342
12.82		Once in 50 years	$4,559,759
12.92		Once in 100 years	$6,181,440
13.03		Once in 200 years	$8,594,152

Sources: Bureau of Meteorology, North East Catchment Management Authority.

Soil retention

Description of ecosystem service and users

Forests in RFA regions provide soil retention services, as vegetation cover helps prevent erosion. Households, government and industry are all users of this service. For example, households or businesses in areas adjacent to forests may benefit from the prevention of landslides. In particular, the water industry benefits from avoided sediment erosion into water supply systems across the state.

This section focuses on how soil retention helps mitigate sedimentation of water supply systems. However, as noted above, soil retention may contribute to other benefits such as prevention of landslides, meaning that the ecosystem service is only partially assessed and valued.

Quantification of ecosystem service

A counterfactual scenario is constructed to assess the reduction in soil erosion that can be attributed to forests. As for water flow regulation, two options are considered and modelled: one that replaces all forest cover with pasture and one that replaces all forest cover with bare earth. These counterfactual scenarios are modelled from 2008 to 2018 using BioSim, alongside the same current forest extent scenario that is used to assess the ecosystem service of water provision and water flow regulation.

The pasture scenario is a similar approach to that used in 2015 to assess water-related services provided by Victoria's parks.[96] However, the bare earth scenario has been used in this study as it reflects emerging consensus in ecosystem accounting that ecosystem services should be assessed against a counterfactual of no vegetation cover, or bare earth.[97] Pasture, for example, is simply another type of ecosystem.

Total soil erosion from grid cells of origin is modelled under each scenario. However, the quantity of soil that is discharged to major waterways (which is a subset of total soil erosion) is calculated, with 82 per cent of soil assumed to be deposited in the catchment before reaching a major waterway.[98] Avoided soil erosion to major waterways is reported as the measure of the ecosystem service, as this has a more clearly identified user (the water industry). However, in an ecosystem accounting framework, soil erosion that is deposited in catchments still has an impact as it would affect the condition of ecosystem assets, and the ecosystem services these assets can generate.

Figure 29 shows average annual erosion (for the modelled time period of 2008 to 2018) across RFA regions for both forest and non-forest areas. Yield ranges from less than 0.1 tonne of sediment per hectare per year in large parts of the state, to more than 5 tonnes per hectare per year (e.g. in parts of the North East RFA region).

Figure 30 shows the increase in average annual erosion that occurs under a counterfactual scenario where current forest cover is replaced with pasture. The modelled increase in erosion ranges from 0 to more than 5 tonnes of sediment per hectare per year. There are significant increases in erosion in parts

96. Department of Environment, Land, Water and Planning and Parks Victoria 2015, Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits, State of Victoria, Melbourne.
97. For example see discussion in Harris, R, Portela, R, Alam, M, Dvarskas, A, Ometto Bezerra, M, Hein, L, Chaplin-Kramer, B, Burkhard, B, Crossman, N, Obst, C & Barton, DN 2019, *Ecosystem services cross-cutting issues: Summary paper*, prepared for the 2019 Forum of Experts in SEEA Experimental Ecosystem Accounting, 26-27 June 2019, Glen Cove, New York, version of 14 June 2019.
98. This approach is in line with the hydrological analysis undertaken by Alluvium for the Valuing Victoria's Parks project. Marsden Jacob Associates 2014, *Valuing the water services provided by Victorian parks*, report prepared for Parks Victoria, Annexure C.

of the North East and Gippsland RFA regions (alpine area and Wilson's Promontory) as well as the Central Highlands and East Gippsland RFA regions.

Figure 31 shows the increase in average annual erosion that occurs under a counterfactual scenario where current forest cover is replaced with bare earth. The modelled increase in erosion ranges from 1 to more than 2,500 tonnes of sediment per hectare per year. The increase in erosion is significantly larger under the bare earth counterfactual (compared to under the pasture counterfactual). While pasture may seem the most *realistic* counterfactual scenario, the bare earth counterfactual is used to estimate the quantity of soil retention services provided by forests in this study, as discussed above.

Compared to a bare earth counterfactual scenario, forests in Victorian RFA regions prevent, on average, 4,344 million tonnes of total soil erosion per year. Forests prevent a portion of this (782 million tonnes per year) from discharging into major waterways. Annual data over the time period modelled is presented in Table 33 and Table 34.

The volume of soil erosion prevented varies significantly from year to year, depending on the severity and timing of rainfall events. On average, soil retention by forests is greatest in the North East RFA region, both in terms of total quantity of soil erosion prevented and the quantity per hectare. This is followed by the Gippsland and East Gippsland RFA regions in terms of total quantity. The total quantity of soil erosion prevented by forests in the Central Highlands RFA region is lower, but is comparable with East Gippsland in per hectare terms. The quantity of erosion prevented in the West RFA region is low in total quantity and quantity per hectare – this is largely due to low relief terrain and less rainfall resulting in lower erosion rates

Valuation of ecosystem service

The ecosystem service of soil retention can be valued based on the avoided cost of repairing damages incurred due to soil erosion under the bare earth counterfactual scenario, such as the cost of dredging waterways to remove sediment. This is among a number of approaches for directly valuing soil retention services identified in a recent discussion paper for the SEEA revision process.[99] This approach requires clearly identifying users or beneficiaries of the ecosystem service, and reasonable actions that could be used to repair damage caused by the loss of soil retention services.

There is limited information available on the cost of sediment removal from inland waterways. A cost estimate from 2007 and 2008 in Western Australia was $17 per tonne.[100] This cost can be applied to the quantity of soil erosion to major waterways across RFA regions. A key limitation of this approach is that it assumes there is demand for the removal of all of the increased sediment by artificial means. This is partly addressed by applying the cost estimate to soil erosion to regulated water systems (systems that have water storages or weirs) to derive a lower bound value. This does not mean that soil erosion to unregulated systems does not have a cost – it undoubtably has a direct or indirect impact on households and industries (such as the agricultural industry) – but rather that the level of demand for the ecosystem service is less established. Consequently, an upper bound value is derived that includes the cost of removing sediment from unregulated waterways.

99. Burkahrd, B, Guerra, CA & Davidsdottir, B 2019, *Discussion paper 3: Soil retention (regulating) ecosystem services*, paper submitted to the Expert Meeting on Advancing the Measurement of Ecosystem Services for Ecosystem Accounting, New York, 22-24 January 2019 and subsequently revised, version of 15 April 2019.

100. Department of Water 2009, *Water notes for river management: Advisory notes for land managers on river and wetland restoration*, WN38 February 2009, Government of Western Australia, Perth.

Table 35 and Table 36 present the lower and upper bound valuation results. The value of soil retention services is most significant in the North East RFA region ($1.8–2.8 billion in 2018). This is driven by the extent of forest in this region, the high relief terrain and the fact that forests prevent significant volumes of soil erosion from being discharged to regulated waterways. The value of soil retention services provided by forests in the East Gippsland RFA region is highly dependent on the value placed on avoided soil erosion of unregulated waterways. The West RFA region has a comparatively low value of soil retention services ($179–568 million) largely due to the low relief terrain in this part of the state and the fact that forests prevent lower volumes of soil erosion from being discharged to regulated waterways.

Given the difficultly in estimating the level of demand for this ecosystem service, and the lack of location specific replacement or damage cost information, the value of soil retention services should be interpreted as an indicative estimate only. However, both the quantity of avoided soil erosion to major waterways and indicative estimates of the value of the ecosystem service illustrate that soil retention is a significant ecosystem service provided by forests across RFA regions.

Figure 29 Average annual erosion across RFA regions under the forest scenario (2008–2018)

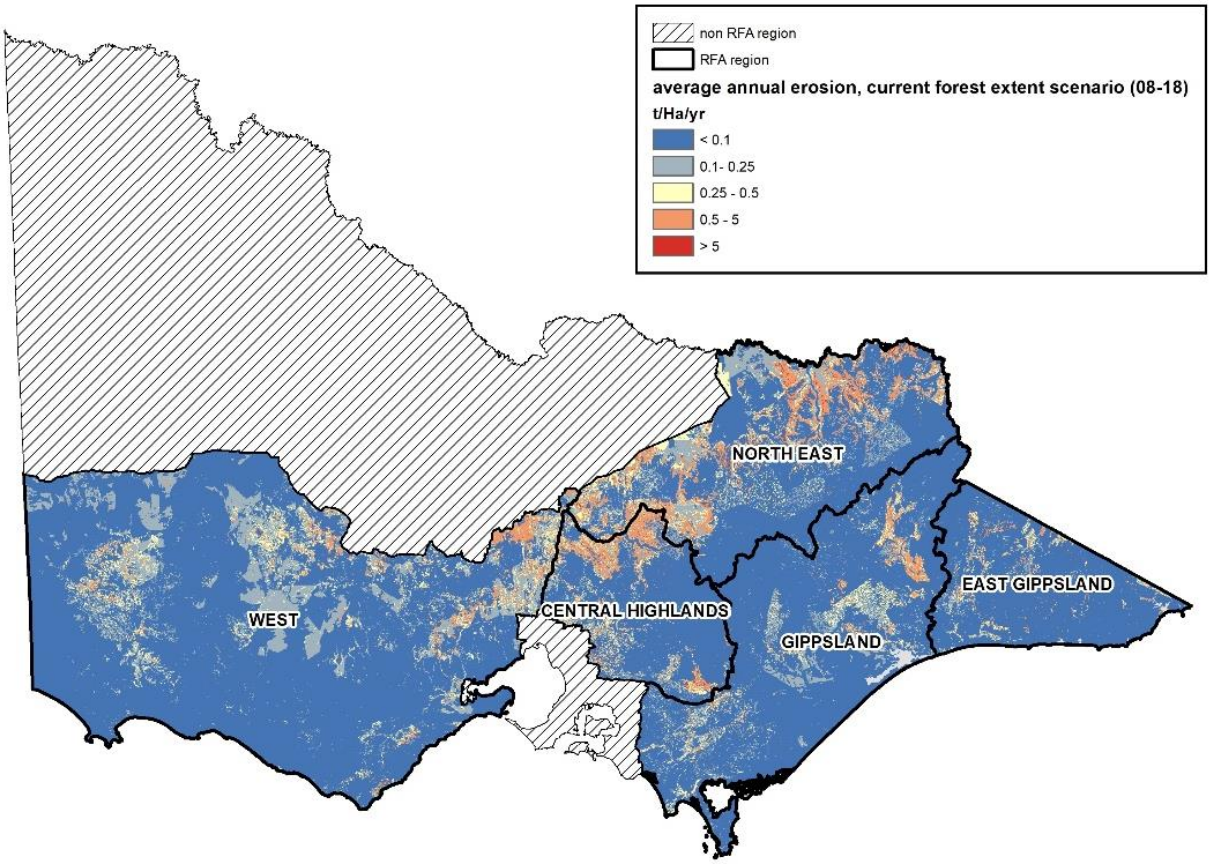


Figure 30 Increase in average annual erosion under a pasture scenario, compared to the forest scenario (2008–2018)

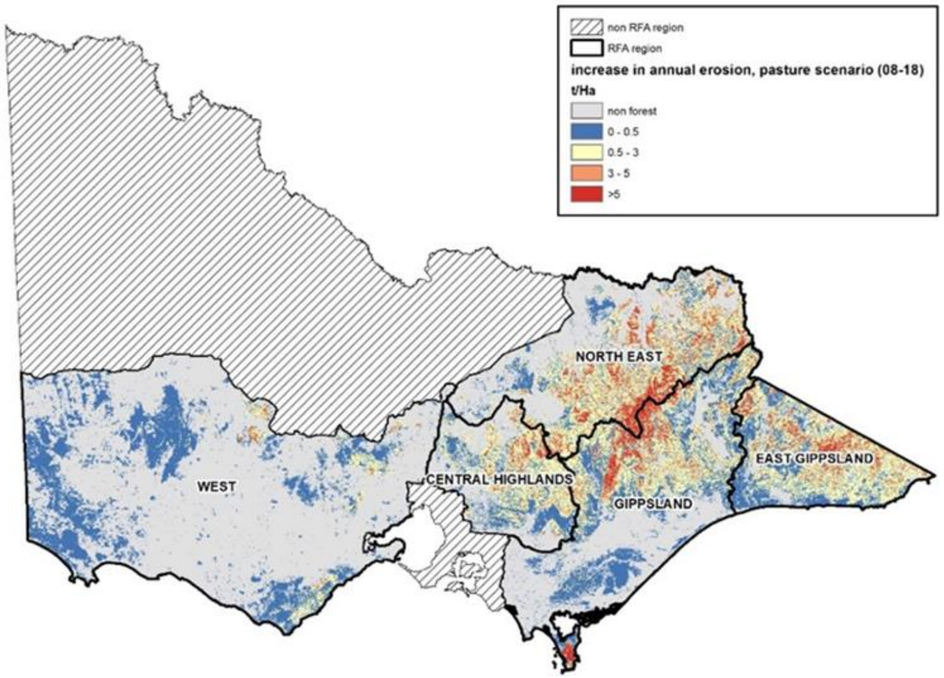


Figure 31 Increase in average annual erosion under a bare earth scenario, compared to the forest scenario (2008–2018)

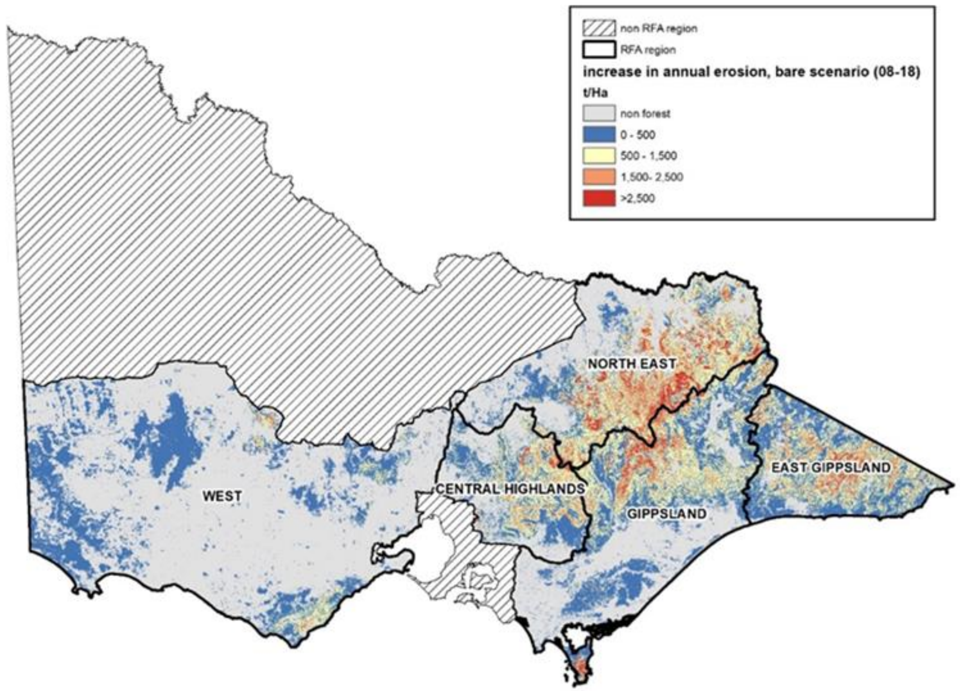


Table 33 Total quantity of erosion prevention (soil retention) by forests in RFA regions, compared to a bare earth counterfactual (tonnes)

RFA region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Central Highlands	318,718,625	382,001,135	906,200,286	881,626,007	744,621,210	566,962,582	419,028,742	207,639,835	467,082,381	600,786,645	321,626,509
East Gippsland	604,750,326	316,903,786	785,644,854	1,031,402,655	1,384,628,792	1,127,114,787	1,270,884,630	1,027,768,227	1,143,102,994	277,046,503	459,201,611
Gippsland	618,803,216	450,145,364	1,457,803,969	1,501,416,810	2,086,857,861	1,288,665,458	1,146,218,311	766,153,181	1,561,886,384	799,224,897	441,288,111
North East	660,249,120	833,173,505	3,728,245,907	2,161,520,537	2,286,719,079	1,522,165,199	1,195,347,370	903,808,544	2,504,337,308	1,738,890,697	749,685,194
West	122,790,714	148,313,852	343,778,043	333,406,672	214,160,144	201,935,137	99,636,778	102,121,911	235,692,721	180,826,155	150,185,234
Total	2,325,312,001	2,130,537,642	7,221,673,059	5,909,372,681	6,716,987,087	4,706,843,162	4,131,115,830	3,007,491,698	5,912,101,788	3,596,774,896	2,121,986,658

Table 34 Quantity of erosion prevention to major waterways by forests in RFA regions, compared to a bare earth counterfactual (tonnes)

RFA region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Central Highlands	57,369,353	68,760,204	163,116,051	158,692,681	134,031,818	102,053,265	75,425,174	37,375,170	84,074,829	108,141,596	57,892,772
East Gippsland	108,855,059	57,042,681	141,416,074	185,652,478	249,233,183	202,880,662	228,759,233	184,998,281	205,758,539	49,868,370	82,656,290
Gippsland	111,384,579	81,026,166	262,404,714	270,255,026	375,634,415	231,959,783	206,319,296	137,907,573	281,139,549	143,860,481	79,431,860
North East	118,844,842	149,971,231	671,084,263	389,073,697	411,609,434	273,989,736	215,162,527	162,685,538	450,780,716	313,000,325	134,943,335
West	22,102,329	26,696,493	61,880,048	60,013,201	38,548,826	36,348,325	17,934,620	18,381,944	42,424,690	32,548,708	27,033,342
Total	418,556,160	383,496,776	1,299,901,151	1,063,687,083	1,209,057,676	847,231,769	743,600,849	541,348,506	1,064,178,322	647,419,481	381,957,598

Table 35 Value of erosion prevention to major waterways by forests in RFA regions – lower bound ($)

RFA region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Central Highlands	670,934,706	859,598,572	1,871,873,829	1,821,534,956	1,808,805,224	1,267,146,762	892,054,854	415,217,633	1,039,796,727	1,310,320,203	654,795,653
East Gippsland	568,868	329,651	1,189,281	914,847	1,341,695	627,755	1,219,299	478,081	1,359,306	289,063	430,565
Gippsland	598,737,470	596,822,926	2,230,975,269	1,487,535,315	2,302,644,584	1,233,501,319	1,033,897,332	614,271,902	1,607,167,991	1,049,167,776	460,405,353
North East	1,596,340,749	2,017,220,408	8,935,734,122	5,196,058,002	5,518,918,317	3,692,491,273	2,961,047,016	2,082,512,519	5,779,256,141	4,002,743,201	1,759,320,778
West	141,575,040	227,485,863	540,111,272	540,204,245	265,434,926	234,645,390	107,434,759	139,098,538	352,980,352	228,411,649	178,571,451
Total	3,008,156,833	3,701,457,420	13,579,883,773	9,046,247,365	9,897,144,747	6,428,412,499	4,995,653,260	3,251,578,673	8,780,560,517	6,590,931,891	3,053,523,799

Table 36 Value of erosion prevention to major waterways by forests in RFA regions – upper bound ($)

RFA region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Central Highlands	1,204,756,404	1,443,964,289	3,425,437,080	3,332,546,307	2,814,668,174	2,143,118,559	1,583,928,645	784,878,576	1,765,571,399	2,270,973,518	1,215,748,204
East Gippsland	2,285,956,232	1,197,896,310	2,969,737,547	3,898,702,036	5,233,896,833	4,260,493,894	4,803,943,900	3,884,963,900	4,320,929,317	1,047,235,780	1,735,782,088
Gippsland	2,339,076,155	1,701,549,476	5,510,499,004	5,675,355,541	7,888,322,716	4,871,155,433	4,332,705,215	2,896,059,023	5,903,930,532	3,021,070,109	1,668,069,060
North East	2,495,741,675	3,149,395,850	14,092,769,530	8,170,547,631	8,643,798,120	5,753,784,451	4,518,413,058	3,416,396,295	9,466,395,026	6,573,006,834	2,833,810,032
West	464,148,899	560,626,361	1,299,481,004	1,260,277,219	809,525,346	763,314,818	376,627,021	386,020,825	890,918,486	683,522,865	567,700,183
Total	8,789,679,365	8,053,432,286	27,297,924,164	22,337,428,734	25,390,211,189	17,791,867,154	15,615,617,839	11,368,318,619	22,347,744,759	13,595,809,108	8,021,109,567

Carbon sequestration and storage

Description of ecosystem service and users

Forests in Victorian RFA regions sequester carbon dioxide from the atmosphere and store it as organic carbon in plant biomass (trunks, branches, foliage and roots) and soil. Carbon is emitted to the atmosphere from forest ecosystems due to disturbances such as fire or the degradation of vegetation and soils. Carbon is also removed from forest ecosystems when biomass is harvested or collected, and is stored in wood products until burned or degraded.

Carbon stored in plant biomass and soils is a stock. The sequestration and emission (or removal) of carbon from forest ecosystems are flows. The change in carbon stock over time will be equal to the net balance of carbon sequestered and emitted/removed from a forest ecosystem.

Forests can sequester and store large amounts of carbon over long time periods, which plays a vital role in regulating the earth's climate and mitigating climate change. The user of carbon related ecosystem services is the Victorian community, as well as the Australian and global communities who benefit from reduced impacts of climate change.

Carbon sequestration

The definition and measurement of carbon related services in ecosystem accounting is a complex and developing area.[101] In this study, carbon sequestration is defined as the gross addition to forest carbon stock. That is, the removal of carbon from the atmosphere and storage in plant biomass as an ecological function. This definition of the ecosystem service aligns with studies such as the experimental woodlands ecosystem accounts developed by Defra in the United Kingdom.[102] However, other studies have focused on net change in carbon stock (known as net ecosystem carbon balance or NECB), such as the 2017 experimental ecosystem accounting study of the Central Highlands.[103] NECB equates to all carbon sequestered by a forest ecosystem in a time period less all carbon emitted/removed, including carbon losses due to disturbances such as fire and harvesting.

Both NECB and carbon sequestration (i.e. gross addition to carbon stock) are useful metrics that can inform policy and management decision making, and both are quantified and reported in this study. However, this study defines the ecosystem service of carbon sequestration as the gross addition to forest carbon stock as this maintains consistency with the conceptualisation of other ecosystem services, such as air filtration, which are typically measured as the gross accumulation of substances as an ecosystem function, rather than net.

101. For example see recent discussion paper developed to inform the SEEA revision process: Edens, B, Elsasser, P, Ivanov, E 2019, *Discussion paper 6: Defining and valuing carbon related services in the SEEA EEA*, paper submitted to the Expert Meeting on Advancing the Measurement of Ecosystem Services for Ecosystem Accounting, New York, 22-24 January 2019 and subsequently revised, version of 15 March 2019.

102. Eftec 2015, *Developing UK natural capital accounts: Woodland ecosystem accounts*, report prepared for the Department for Environment, Food and Rural Affairs, London.

103. Keith, H, Vardon, M, Stein, J, Stein J & Lindenmayer, D 2017a, *Experimental ecosystem accounts for the Central Highlands of Victoria: Final report*, Australian National University Fenner School of Environment and Society, Canberra; Keith, H, Vardon, M, Stein, J, Stein J & Lindenmayer, D 2017b, *Experimental ecosystem accounts for the Central Highlands of Victoria: Appendices*, Australian National University Fenner School of Environment and Society, Canberra.

Carbon storage

In addition to carbon sequestration, carbon storage can be conceptualised as a distinct ecosystem service defined as the avoided flow of carbon resulting from maintaining the stock of carbon sequestered in an ecosystem.[104] Measuring this ecosystem service would entail estimating avoided carbon emissions. That is, stored carbon that is at clear risk of being released in the short term. No service flow would be recorded if stocks at risk of being released are actually released, but positive service flows would be recorded if stocks at risk remain in storage. Carbon storage as an ecosystem service is not quantified and valued in this study, however this is a potential area for future work in Victoria. Forest carbon stock is reported *as an indicator* of the ecosystem service of carbon storage. However, this should not be confused as an actual measure of the ecosystem service, as it does not take into account the risk of carbon being released.

Quantification of ecosystem service

Carbon stock (an indicator of the ecosystem service of carbon storage)

Biomass data has been used to calculate the stock of above ground carbon in forests across Victoria. This includes living and dead above ground biomass, but not below-ground biomass (root systems) or soil carbon. Biomass data was supplied from the Victorian Forest Monitoring Program (VFMP) and was created by integrating Landsat satellite timeseries with Victoria's forest monitoring and forecasting framework. A conversion factor of 0.47 is used to convert biomass to carbon.[105]

In 2017, an estimated 1.1 billion tonnes of carbon was stored in above ground biomass on public land across Victorian RFA regions,[106] which is around 4 billion tonnes of carbon dioxide equivalent (CO2e).[107] Carbon stocks fluctuate from year to year, due to a range of factors including bushfires. From 1988 carbon stocks have averaged 1 billion tonnes, with a high of 1,091 million tonnes in 1989 and a low of 895 million tonnes in 2007 (see Figure 32 and Table 38).[108] There were significant bushfires in 2006–2007 which contributed to this reduction in carbon stocks, particularly in the Gippsland and North East RFA regions. The impact of other major bushfire seasons can be seen in the data, such as the 2003 bushfires in the Gippsland and North East RFA regions, the 2009 bushfires in the Central Highlands, and the 2014 bushfires in East Gippsland. There has been a steady increase in carbon stocks over the past decade, driven by increases in the Gippsland and North East RFA regions.

The Gippsland RFA region has the largest carbon stock on public land (289 million tonnes in 2017), followed by North East and East Gippsland (both 242 million tonnes of carbon in 2017). However,

104. There are divergent views on whether carbon storage is a distinct ecosystem service. A discussion paper prepared for the SEEA revision process proposes that carbon storage should not be seen as a distinct ecosystem service. However, the current SEEA framework defines the ecosystem service of carbon storage as 'the avoided flow of carbon resulting from maintaining the stock of above- and below-ground carbon sequestered in the ecosystem', where 'avoided emissions relate only to the part of the stored carbon that is at clear risk of being released in the short term'. See Edens, B, Elsasser, P, Ivanov, E 2019, Discussion paper 6: Defining and valuing carbon related services in the SEEA EEA, paper submitted to the Expert Meeting on Advancing the Measurement of Ecosystem Services for Ecosystem Accounting, New York, 22-24 January 2019 and subsequently revised, version of 15 March 2019; United Nations 2014, System of environmental-economic accounting 2012: Experimental ecosystem accounting, United Nations, New York, pp. 65-66.

105. Gifford, R 2000, *Carbon contents of above-ground tissues of forest and woodland trees*, National Carbon Accounting System Technical Report No. 22, Australian Greenhouse Office, Canberra, p. 24.

106. Includes carbon stored in forest on public land, and other vegetation (shrubland, grassland and wetland) on public land. The proportion stored in other vegetation (shrubland, grassland and wetland) on public land is less than 4 per cent.

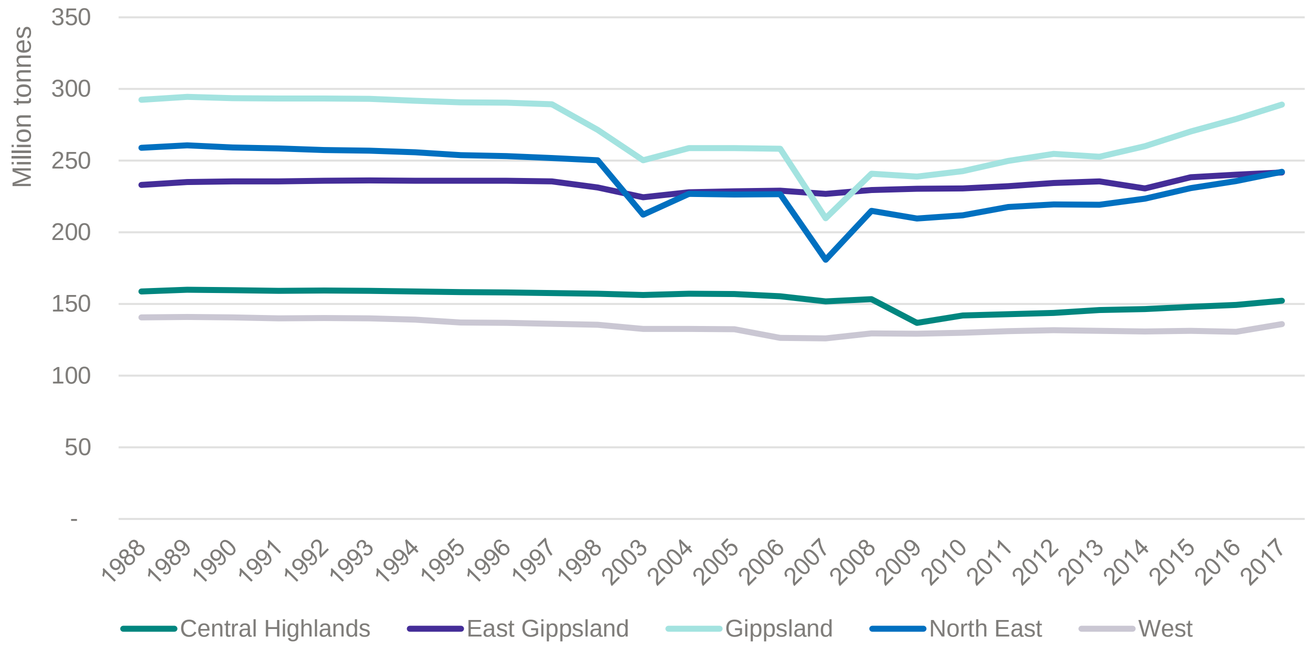
107. 1 tonne of carbon = 3.664 tonnes of carbon dioxide equivalent. See Department of the Environment and Energy 2017, *National greenhouse accounts factors: Australian national greenhouse accounts*, Commonwealth of Australia, Canberra.

108. Note that there is a gap in the dataset, with data unavailable for 1999, 2000, 2001 and 2002.

Gippsland, East Gippsland and the North East RFA regions have larger areas of forests on public land than the Central Highlands and West RFA regions.

Figure 33 shows the distribution of above ground carbon stocks on public land across Victoria in 2017. It shows the significant density of carbon storage in forests in the east of the state, and in the Otway Ranges in the West RFA region, reaching more than 250 tonnes of carbon per hectare.

Figure 32 Above ground carbon stocks in forests on public land (1988–2017)



Note that data is not available for 1999-2002.

Figure 33 Above ground carbon stock in forests on public land (2017)

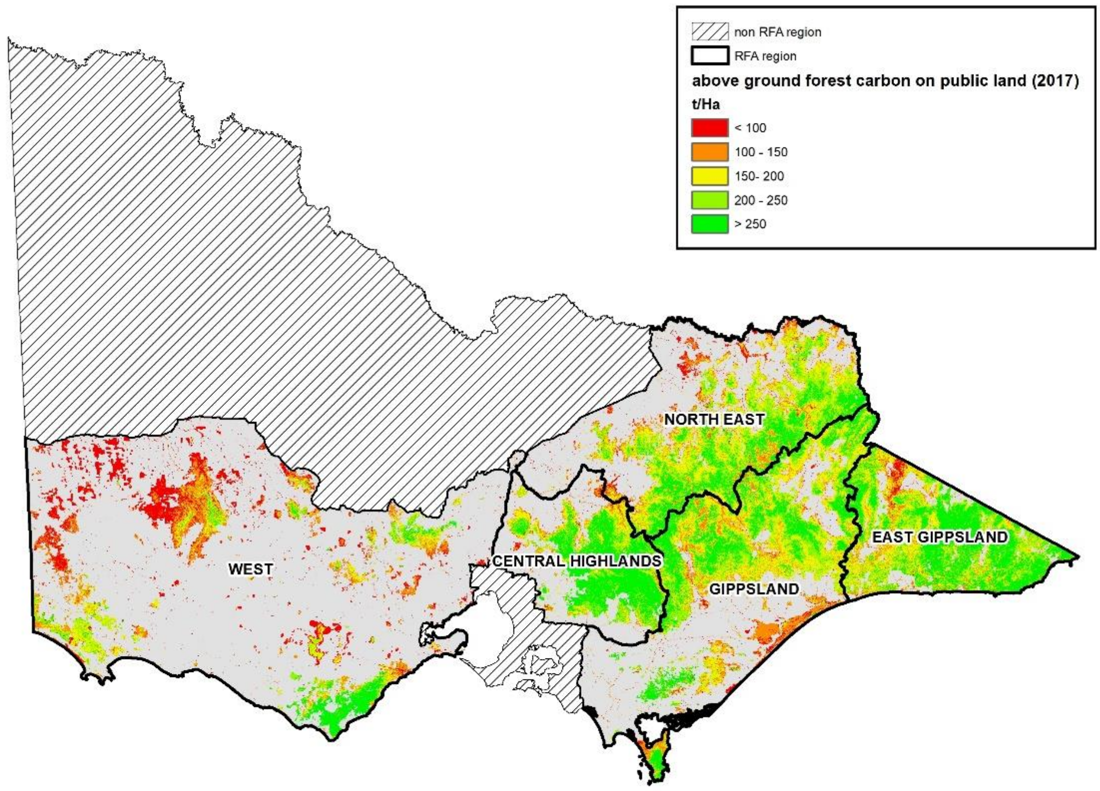


Figure 34 shows the change in carbon stocks between 2006 and 2007, a period of significant bushfire activity and loss of forest carbon stocks. The 2007 fire extent is also mapped. The reduction in carbon stocks from the 2007 Alpine fires in the east of the state is clearly evident. The map also shows carbon stocks recovering in the Grampians in the West RFA region from the 2006 fires.

Figure 34 Change in above ground carbon stock in forests on public land between 2006 and 2007

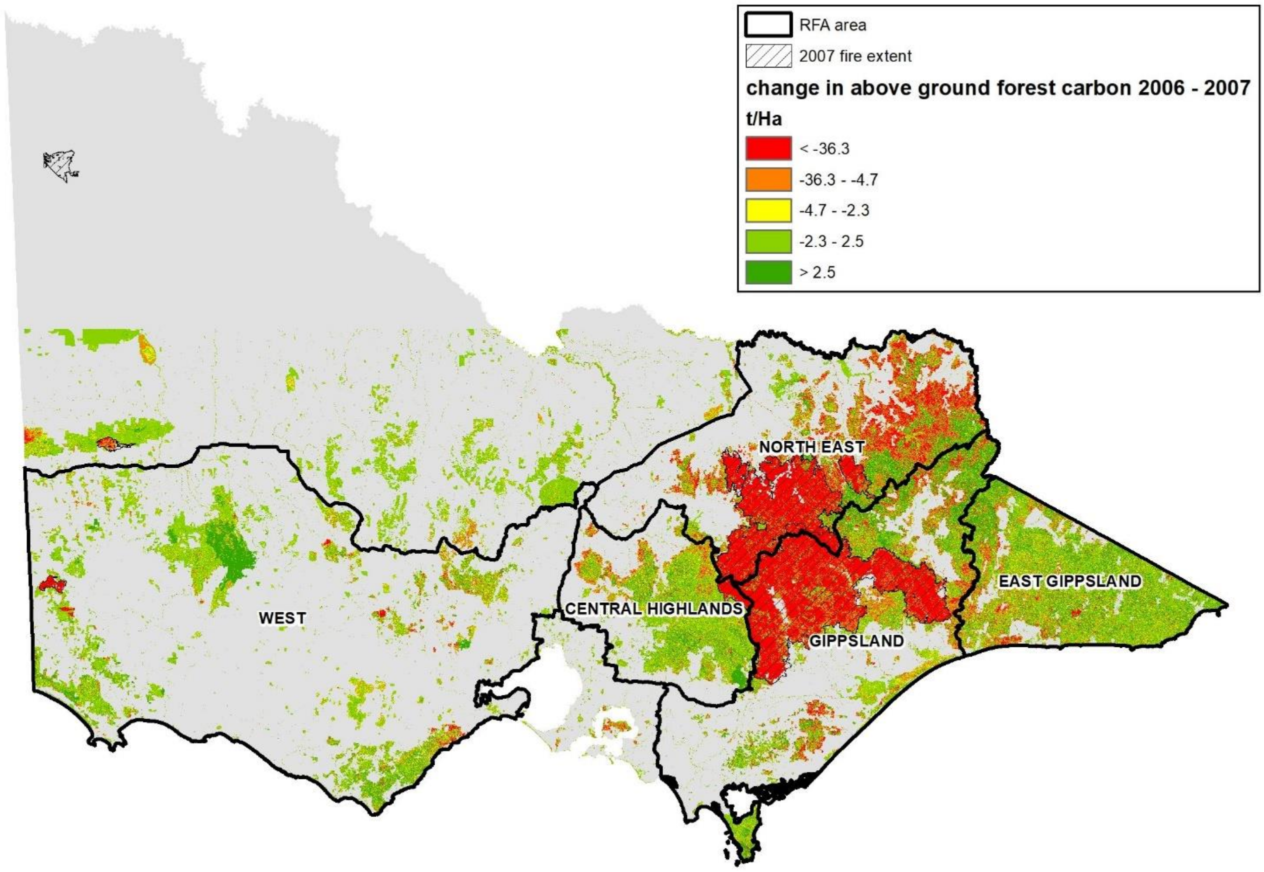


Table 37 presents a carbon stock account for 2008 to 2009. This year was selected as an example of a year where losses due to fire, timber harvesting and other factors are clearly evident, with 2009 being a year of significant bushfires. In 2009 there was a net loss in carbon stocks in forests on public land across RFA regions, with carbon stocks increasing in subsequent years.

The account shows additions to carbon stock in each RFA region due to carbon sequestration as well as reductions to stock due to bushfire, harvesting and other factors. Significant reductions due to fire are evident in the Central Highlands RFA region, which corresponds with large fires in this region in this year, including the Black Saturday bushfires in February 2009 (see Figure 36). In this time period, there was a net loss in carbon stocks in all RFA regions except for East Gippsland.

To isolate annual gross reductions in carbon stock and attribute these losses to bushfire or timber harvesting annual carbon stocks were subtracted from the proceeding year’s carbon stock to produce a dataset of annual carbon change. Timber harvesting and fire history datasets for each corresponding year were then used to define carbon losses as either bushfire, harvesting or other (for further information refer to Appendix D). In some areas where both harvesting and bushfire has occurred it is not known what proportion of the reduction in carbon stock can be attributed to each, and they are grouped together. ‘Other’ includes reductions in carbon stock due to factors such as the natural dynamics of the forest, natural disturbances such as dieback and storms, and climatic factors such as drought. While the quantity of reductions in stock due to other factors is significant, reductions are reasonably evenly distributed across the landscape, while reductions due to fire or harvesting occur in concentrated areas. Significant reductions due to other factors correspond with significant additions (carbon sequestration) across the RFA regions.

Carbon losses (reductions) in each RFA region in each year are presented in Table 39, while carbon sequestration (additions) in each RFA region in each year is presented in Table 40.

Table 37 Carbon stocks[a] in forests in Victorian RFA regions (tonnes, 2008–2009)

	Central Highlands	East Gippsland	Gippsland	North East	West	Total
Opening stock (2008)	153,259,847	229,433,638	240,866,041	215,061,773	129,373,641	967,994,940
Additions to stock						
Sequestration	1,416,617	4,288,823	5,864,214	2,547,184	2,345,195	16,462,032
Total additions to stock	1,416,617	4,288,823	5,864,214	2,547,184	2,345,195	16,462,032
Reductions to stock						
Fire	16,133,077	57,160	1,933,425	934,298	46,178	19,104,138
Harvesting	1,546,055	210,535	76,845	8,329	441	1,842,205
Fire and harvesting[b]	134,318	10,156	-	-	-	144,475
Other[c]	68,996	3,140,272	5,781,221	6,944,522	2,518,671	18,453,682
Total reductions to stock	17,882,447	3,418,123	7,791,491	7,887,149	2,565,290	39,544,500
Closing stock (2009)	136,794,017	230,304,338	238,938,764	209,721,808	129,153,546	944,912,472
Net ecosystem carbon balance	-16,465,830	870,700	-1,927,278	-5,339,965	-220,095	-23,082,468

(a) Carbon stocks in above ground biomass on public land only. (b) Reductions in stock either due to fire or harvesting, but cannot be attributed. (c) Other includes reductions in carbon stock due to factors such as the natural dynamics of the forest, natural disturbances such as dieback and storms, and climatic factors such as drought.

Carbon sequestration

To measure the ecosystem service of carbon sequestration, annual gross additions to carbon stock are isolated and quantified. This data is presented in Table 40. Carbon sequestration was 41 million tonnes across public forests in RFA regions in 2017. Carbon sequestration can vary significantly from year to year, as the flow of this ecosystem service is related to disturbance events that impact on the condition of the ecosystem assets. For example, in 2009 just 16 million tonnes was sequestered (which aligns with ‘additions to stock’ in Table 37). Forests will typically generate a higher ecosystem service flow after bushfires, harvesting or drought as vegetation regenerates. This can be seen in the data in 2008 (see Table 40 and Figure 35) where carbon sequestration is significant in the Gippsland and North East RFA regions (34 and 36 million tonnes of carbon sequestration respectively) after large fires in these regions in 2006–2007.

Valuation of ecosystem service

Carbon sequestration

The ecosystem service of carbon sequestration can be valued by applying a dollar value to each tonne of carbon dioxide equivalent (CO2e). One tonne of carbon is equal to 3.664 tonnes of CO2e.[109] The values used in this analysis are:

- Lower bound - $12 per tonne of CO2e
- Central - $20 per tonne of CO2e
- Upper bound - $59 per tonne of CO2e

In the absence of a clear carbon price in Australia, the central value has been derived from a median of existing international carbon market values, which were obtained from the World Bank Carbon Pricing Dashboard data.[110] Upper and lower bound values can be used for sensitivity testing. The upper bound value is equivalent to the 2018 social cost of carbon estimate derived by the US Environment Protection Agency.[111]

The upper bound value represents a different method of valuing the ecosystem service of carbon sequestration, based on a welfare value. This differs from exchange values which are used to value other ecosystem services in this study.

In 2017, the value of the ecosystem service of carbon sequestration is estimated at $3 billion, with an upper and lower bound of $1.8 billion and $8.7 billion. Annual valuation using the central value (which is an exchange value) is presented in Table 41.

109. Department of the Environment and Energy 2017, *National greenhouse accounts factors: Australian national greenhouse accounts*, Commonwealth of Australia, Canberra.

110. World Bank's Carbon Pricing Dashboard: http://carbonpricingdashboard.worldbank.org/map_data

111. Interagency Working Group on Social Cost of Greenhouse Gases 2016, *Technical support document: Technical update of the social cost of carbon for regulatory impact analysis – Under Executive Order 12866*, United States Government.

Figure 35 Change in above ground carbon stock in forests on public land 2008

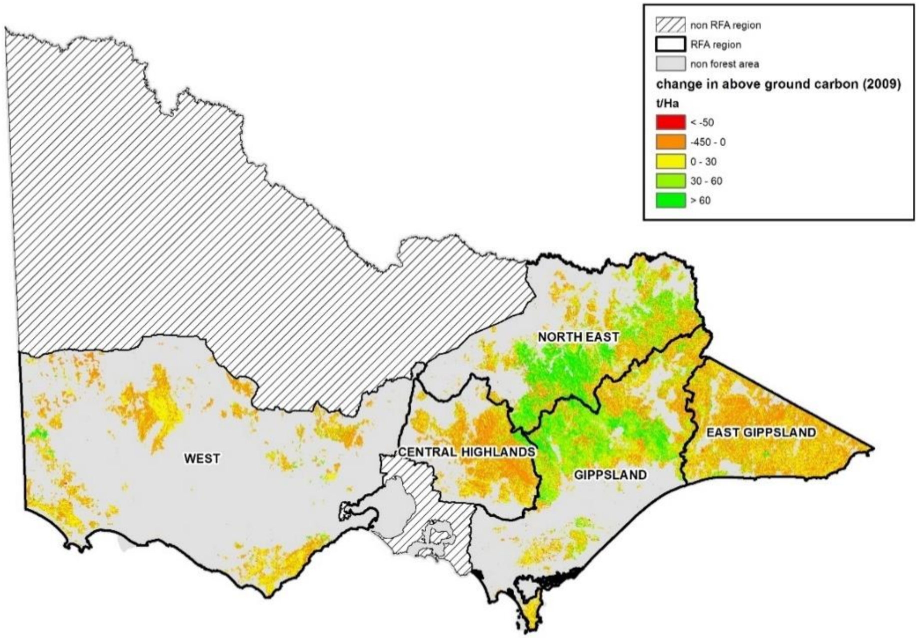


Figure 36 Change in above ground carbon stock in forests on public land 2009

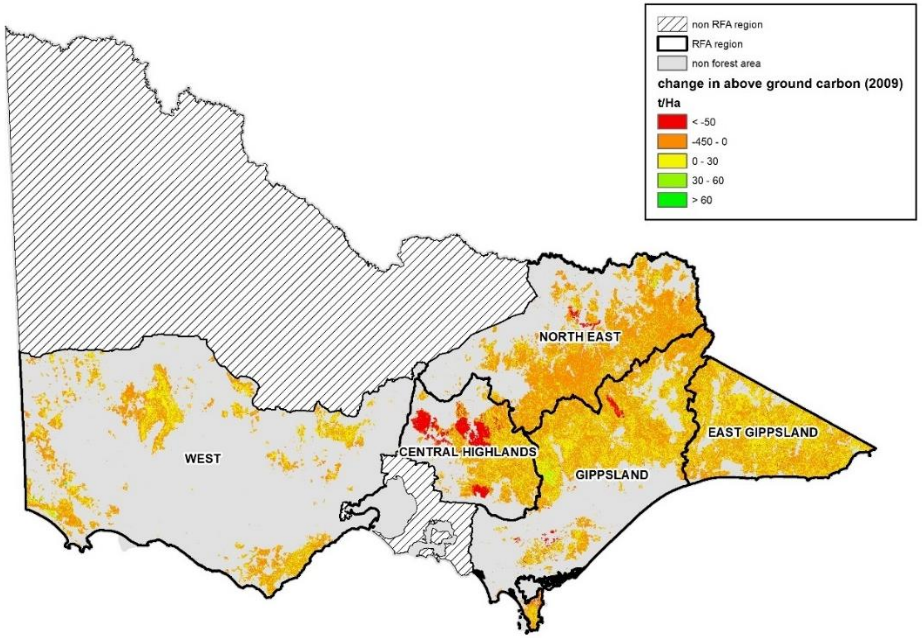


Table 38 Above ground carbon stocks[a] in forests on public land in Victorian RFA regions (tonnes, 1998–2017)[a]

RFA region	1988	1989	1990	1991	1992	1993	1994	1995	1996
Central Highlands	158,715,787	159,921,446	159,508,373	159,203,660	159,369,321	159,177,790	158,779,852	158,178,543	158,055,297
East Gippsland	233,124,542	235,075,693	235,586,884	235,596,779	236,069,145	236,283,843	236,045,009	235,922,025	235,944,144
Gippsland	292,500,069	294,498,724	293,554,002	293,285,679	293,334,889	293,034,543	291,892,212	290,689,222	290,500,860
North East	259,063,722	260,666,521	259,144,443	258,439,268	257,406,708	257,050,674	255,743,221	253,897,885	253,049,878
West	140,538,846	140,921,414	140,719,342	139,921,469	140,080,648	139,948,845	139,068,222	137,054,994	136,924,181
Total	1,083,942,966	1,091,083,798	1,088,513,045	1,086,446,856	1,086,260,711	1,085,495,695	1,081,528,516	1,075,742,669	1,074,474,359

RFA region	1997	1998	2003	2004	2005	2006	2007	2008	2009
Central Highlands	157,531,427	157,067,744	156,165,243	157,180,983	156,816,525	155,383,285	151,856,734	153,259,847	136,794,017
East Gippsland	235,548,256	231,178,795	224,436,545	227,821,677	228,569,454	228,958,284	226,826,386	229,433,638	230,304,338
Gippsland	289,318,839	271,561,547	250,148,807	258,770,674	258,736,789	258,248,651	209,795,154	240,866,041	238,939,012
North East	251,751,685	250,198,341	212,401,634	226,815,211	226,367,716	226,656,948	180,834,401	215,061,773	209,722,374
West	136,143,224	135,376,046	132,660,845	132,608,740	132,314,318	126,363,660	125,981,478	129,373,641	129,153,546
Total	1,070,293,431	1,045,382,473	975,813,074	1,003,197,286	1,002,804,802	995,610,826	895,294,152	967,994,940	944,913,286

RFA region	2010	2011	2012	2013	2014	2015	2016	2017
Central Highlands	142,016,920	142,810,895	143,829,791	145,695,087	146,434,798	148,031,688	149,438,923	152,161,090
East Gippsland	230,644,954	232,262,354	234,373,556	235,461,619	230,705,018	238,487,266	240,166,082	241,730,001
Gippsland	242,623,116	249,743,413	254,789,115	252,661,581	260,185,428	270,443,530	279,086,586	289,052,292
North East	211,778,922	217,682,218	219,390,644	219,117,749	223,382,085	230,726,349	235,818,934	242,279,663
West	129,953,078	131,063,422	131,670,785	131,259,821	130,866,747	131,221,008	130,680,297	135,871,573
Total	957,016,991	973,562,302	984,053,891	984,195,856	991,574,076	1,018,909,841	1,035,190,823	1,061,094,620

(a) There is a gap in the data between 1998 and 2003.

Table 39 Carbon losses (reductions) from forests on public land in Victorian RFA regions (tonnes, 2008–2017)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Central Highlands										
Fire	1,423	16,133,077	1,358	4	2	31,677	14,146	313	7,962	86
Harvesting	117,222	68,996	84,389	62,500	35,836	86,221	80,151	166,739	176,451	38,257
Fire and harvesting	-	134,318	113	-	-	1,501	758	-	-	-
Other	2,418,074	1,546,055	1,493,774	1,335,911	1,221,831	1,753,237	2,284,961	1,603,349	1,879,901	2,095,373
Total	2,536,719	17,882,447	1,579,634	1,398,414	1,257,668	1,872,636	2,380,016	1,770,401	2,064,314	2,133,716
East Gippsland										
Fire	30,045	57,160	243,429	334,179	13	18,183	7,642,602	126	35,208	20,557
Harvesting	214,498	210,535	116,878	156,901	80,653	66,549	53,447	104,307	57,715	22,346
Fire and harvesting	-	10,156	34	5,529	-	-	7,672	-	-	-
Other	3,396,026	3,140,272	2,900,401	2,273,667	2,083,746	3,343,382	2,066,282	1,857,028	2,856,859	3,832,168
Total	3,640,569	3,418,123	3,260,742	2,770,276	2,164,413	3,428,114	9,770,003	1,961,461	2,949,782	3,875,072
Gippsland										
Fire	1,605	1,933,425	333	252	33	5,890,989	172,637	7,371	525	7,464
Harvesting	72,612	76,845	9,912	29,112	24,676	18,296	11,452	34,631	32,620	35,144
Fire and harvesting	3	-	-	-	-	1,553	-	-	-	-

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Other	2,688,589	5,781,221	3,938,082	2,399,451	3,369,834	4,252,286	4,196,301	2,628,430	3,614,426	3,895,597
Total	2,762,810	7,791,491	3,948,327	2,428,815	3,394,544	10,163,124	4,380,390	2,670,432	3,647,571	3,938,204
North East										
Fire	471	934,298	49	-	127	1,030,906	140,259	5,329	51,450	13
Harvesting	16,367	8,329	3,000	1,434	2,268	4,618	12,081	8,414	7,016	7,770
Fire and harvesting	-	-	-	-	-	-	-	-	-	-
Other	2,231,948	6,944,522	2,649,255	1,382,194	3,034,674	4,493,331	3,253,271	2,060,825	3,144,018	3,141,039
Total	2,248,786	7,887,149	2,652,304	1,383,628	3,037,069	5,528,855	3,405,611	2,074,568	3,202,484	3,148,821
West										
Fire	41,663	46,178	81,474	956	26,327	996,183	2,014,816	106,290	393,848	702
Harvesting	4,449	441	597	2,577	137	795	374	833	3,531	376
Fire and harvesting	-	-	-	-	-	-	-	-	-	-
Other	1,614,292	2,518,671	1,495,524	1,463,084	1,787,096	2,439,752	2,466,718	2,468,393	3,358,070	2,012,767
Total	1,660,404	2,565,290	1,577,596	1,466,617	1,813,560	3,436,730	4,481,909	2,575,516	3,755,449	2,013,844
Total										
Fire	75,207	19,104,138	326,643	335,391	26,502	7,967,938	9,984,460	119,429	488,992	28,822
Harvesting	425,148	365,146	214,776	252,523	143,570	176,478	157,505	314,924	277,333	103,892

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Fire and harvesting	3	144,475	147	5,529	-	3,055	8,430	-	-	-
Other	12,348,930	19,930,741	12,477,035	8,854,306	11,497,181	16,281,988	14,267,533	10,618,025	14,853,274	14,976,943
Total	12,849,288	39,544,500	13,018,601	9,447,749	11,667,253	24,429,459	24,417,929	11,052,379	15,619,599	15,109,658

Table 40 Carbon sequestration (additions) by forests on public land in Victorian RFA regions (tonnes, 2008–2017)

RFA region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Central Highlands	3,939,832	1,416,617	6,802,537	2,192,389	2,276,563	3,737,932	3,119,727	3,367,291	3,471,549	4,855,883
East Gippsland	6,247,821	4,288,823	3,601,358	4,387,676	4,275,614	4,516,177	5,013,403	9,743,709	4,628,598	5,438,991
Gippsland	33,833,820	5,864,214	7,632,431	9,549,112	8,440,246	8,035,590	11,904,236	12,928,534	12,290,627	13,903,910
North East	36,476,431	2,547,184	4,708,852	7,286,923	4,745,496	5,256,283	7,669,654	9,418,832	8,295,069	9,609,551
West	5,052,567	2,345,195	2,377,128	2,576,961	2,420,923	3,025,855	4,088,714	2,929,777	3,214,738	7,205,592
Total	85,550,472	16,462,032	25,122,306	25,993,061	22,158,842	24,571,838	31,795,734	38,388,143	31,900,581	41,013,926

Table 41 Value of carbon sequestration by forests on public land in Victorian RFA regions ($, 2008–2017)

RFA region	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Central Highlands	288,710,879	103,809,669	498,489,947	160,658,285	166,826,569	273,915,664	228,613,594	246,755,087	254,395,129	355,839,108
East Gippsland	457,840,351	314,284,973	263,907,520	321,528,902	313,316,992	330,945,477	367,382,141	714,018,970	339,183,632	398,569,251
Gippsland	2,479,342,362	429,729,565	559,304,513	699,758,908	618,501,254	588,848,035	872,342,424	947,403,001	900,657,174	1,018,878,517
North East	2,672,992,875	186,657,629	345,064,673	533,985,735	347,749,912	385,180,423	562,032,253	690,212,006	607,862,623	704,187,891
West	370,252,091	171,855,904	174,195,935	188,839,676	177,405,237	221,734,676	299,620,945	214,694,090	235,576,032	528,025,754
Total	6,269,138,559	1,206,337,739	1,840,962,587	1,904,771,506	1,623,799,964	1,800,624,275	2,329,991,357	2,813,083,153	2,337,674,590	3,005,500,520

Pollination

Description of ecosystem service and users

Forests in Victorian RFA regions support native and introduced pollinators that provide pollination services to industries and households. A direct user of this ecosystem service in the apiary industry which provides commercial pollination services to producers of pollination dependent crops. The agricultural industry and households are also direct users of wild pollination services. More broadly, businesses and households benefit from the production and consumption of pollination dependent crops. Pollination is also an important intra and inter-ecosystem flow which supports the maintenance of forests and other types of ecosystems. This assessment focuses on the contribution of forest ecosystems to the apiary industry and to commercial pollination services, and consequently represents a lower bound estimate of the broader contribution of pollination to households and industries.

Forest ecosystems support a range of pollinators such as insects, birds and bats that pollinate plants and are essential to producing fruits, vegetables and seeds for human use. European honeybees are the most common pollinators of agriculture in Australia, while other species, including native bees and other insects, also perform some agricultural pollination.

Pollinators are essential for the production of some crops, while for others they help raise crop yields. The level of dependence on pollination varies, ranging from 10 per cent for peanuts to 90 per cent for apples and 100 per cent for almonds.[112] This means that the removal of pollination would lead to loss of all almond production and significant decline of apple production. Although there are technically feasible substitutes for pollination by bees and other insects, such as artificial pollination by people or technology, the cost would be higher.

Pollination of agricultural crops is highly dependent on access to native floral resources in forests. Providers of commercial pollination services typically store and strengthen bee colonies by placing hives in or near areas of native vegetation. Hives are then transported to agricultural areas to pollinate specific crops (such as Victoria's almond orchards). There are also unpaid pollination services (incidental pollination) from wild pollinators or beekeeping activity.

Quantification of ecosystem service

Habitat for bees and other pollinators

Forests provide habitat that supports bees and other pollinators. Forest ecosystem extent provides a broad indicator of provision of habitat for pollinators, including bees. The maintenance of forest ecosystem extent and condition is crucial to supporting pollinators and pollination services.

Apiary sites

There are 4,485 licensed apiary (beekeeping) sites on public land across Victoria.[113] Fifty-five per cent of sites are in RFA regions, with the largest number in the West RFA region (22 per cent of total sites) followed by Gippsland (13 per cent). Apiary sites are typically located in and around forests. Apiary sites are further discussed, and maps provided, in the honey section of Appendix A.

112. Gordon, J & Davis, L 2003, *Valuing honeybee pollination*, Centre for International Economics, report prepared for the Rural Industries Research and Development Corporation, p 7.

113. Department of Environment, Land, Water and Planning dataset: Apiary rights and bee farm and range licenses

Commercial pollination services

Almonds are the most common crop that uses commercial pollination services in Victoria, with 94 per cent of pollination service providers supplying almond crops – see Table 42. Around 20 per cent of pollination service providers supply oilseed crops, and 10 per cent supply other fruit crops.

Commercial pollination services have increased over the past decade with over 50 per cent of Victorian beekeepers providing commercial pollination services in 2014-15, up from under 40 per cent in 2006-07. Around 14 per cent of Victorian beekeeping businesses not offering commercial pollination services in 2014-15 planned to commence in the next five years, and over 55 per cent of those offering commercial pollination services planned to expand. It is not clear what proportion of the increase in commercial pollination is due to a decline in wild pollination (requiring substitution with commercial pollination) or an increase in crops requiring commercial pollination. However, it is likely driven in part by growth in pollination dependent crops such as almonds, where production has increased significantly in northern Victoria.[114]

Access to public land appears to be sufficient for many beekeepers, as this was not commonly cited as an impediment to commencing or expanding commercial pollination services. Around 10 per cent of Australian beekeepers surveyed in 2014-15 said public land availability was an impediment.[115]

Beekeepers are willing to travel significant distances to deliver commercial pollination services, demonstrating that forests (where bee colonies are stored and strengthened) play a role in supporting agricultural production even when crops are not located near forests. Nationally, the average distance travelled by beekeepers to deliver commercial pollination services in 2014-15 was 310 kilometres, with 50 per cent of beekeepers travelling between 85 and 400 kilometres.[116] It's likely that average distances travelled in Victoria would be lower, due to the density of population and crop production in the state.

Table 42 Types of crops pollinated by commercial pollination service providers, Victoria, 2014-15

Proportion of pollination service providers pollinating crop (%)	
Almonds	94
Cherries	4
Pome fruits	7
Other fruit	11
Oilseeds	18
Vegetables	4
Other	6

114. The Age 2019, 'Almond growers prepare for record harvest but more bees needed to keep industry buzzing', accessed October 2019 at https://www.abc.net.au/news/rural/2019-01-21/almond-industry-booming-but-more-bees-needed/10724074

115. Australian Bureau of Agricultural and Resource Economics and Sciences 2016, *Australian honey bee industry: 2014-15 survey results*, Commonwealth of Australia, Canberra, p. 17.

116. Australian Bureau of Agricultural and Resource Economics and Sciences 2016, *Australian honey bee industry: 2014-15 survey results*, Commonwealth of Australia, Canberra, p. 16.

Note: Beekeeping businesses can pollinate multiple types of crops throughout a given year.

Source: ABARES

Valuation of ecosystem service

Commercial pollination services

The contribution of forests to commercial pollination services can be valued using market information reported by ABARES. In 2014-15, Victorian beekeepers received an average of $27,000 for commercial pollination services. This suggests an average payment of around $70 per hive (as beekeepers reported an average of 380 hives). Although, as not all beekeepers offer commercial pollination services, the average payment per hive used for commercial pollination services would be higher.

The average annual cash costs per beekeeping business in Victoria are $109,500.[117] Attributing a portion of these costs to pollination services, in line with the proportion of average cash receipts that are for pollination services (13 per cent), suggests average annual cash costs for pollination services of around $15,000 per business. This results in an average cash profit (cash receipts less cash costs) of $12,000 per business. Applying this to the number of commercial beekeeping businesses in Victoria (220)[118], the reliance of beekeeping businesses on forested areas (50-70 per cent – see Table 25) and the proportion of apiary sites in RFA regions (55 per cent), the value contributed to commercial pollination services by state forests in RFA regions is estimated at around $750,000 to $1,050,000 per year.

Given the extrapolation of data and assumptions made around the use of apiary sites in RFA regions, confidence in the precision of this estimate is low, and it should be considered an indicative estimate only. However, this represents a lower bound estimate of the value of pollination services, as it is based on the market value of commercial pollination services, rather than the benefit pollination (both commercial and wild) provides to producers and consumers of agricultural products.

Agricultural production

Studies have attempted to derive the economic value of pollination by modelling the loss of producer and consumer surplus (welfare value) that would occur if there was a shock to supply of honeybee pollination dependent agricultural crops.

A 2003 study estimated the value of pollination across Australia to be over $1.7 billion per year.[119] This included producer surplus value of $877 million and consumer surplus value of $839 million, as without pollination reduced supply of some agricultural products would drive higher prices for consumers, or certain products would not be available.

117. Australian Bureau of Agricultural and Resource Economics and Sciences 2016, *Australian honey bee industry: 2014-15 survey results*, Commonwealth of Australia, Canberra, p. 32.

118. Australian Bureau of Agricultural and Resource Economics and Sciences 2016, *Australian honey bee industry: 2014-15 survey results*, Commonwealth of Australia, Canberra, p. 3.

119. Gordon, J & Davis, L 2003, *Valuing honeybee pollination*, Centre for International Economics, report prepared for the Rural Industries Research and Development Corporation.

A 2018 study by Curtin University academics is the most recent attempt to estimate the economic value of pollination.[120] It is also the first research to report values for states and territories: previous studies derived a single economic value of pollination for Australia.[121] The study modelled the impact of a supply shock (due to the absence of pollination) on 53 honeybee pollination dependent agricultural crops, and estimated the economic value of pollination in Victoria as between $3.2 billion to $9.0 billion. This is the highest estimate of all states and territories, which likely represents the composition of agricultural crops grown in Victoria (such as almonds), and the volume and value of agricultural production in Victoria.

This is likely an upper bound estimate of the value of pollination, as it is based on the sudden loss of crops due to the absence of pollination. It assumes low elasticity in demand for pollination dependent agricultural products (limited substitute products) and does not account for alternatives to honeybee pollination that may be used, such as artificial pollination. Nonetheless, forests are crucial to supporting healthy bee populations, and reductions in the extent of forest ecosystems would likely have a significant impact on commercial and wild pollination services and the benefits these provide to producers and consumers of agricultural products.

120. Karasinski, J 2018, *The economic valuation of Australian managed and wild honey bee pollinators in 2014-15*, Curtin University, Perth.

121. Gill, R 1991, ‘The value of honeybee pollination to society’, *Apiacta*, 4, pp. 97-105; Gordon, J & Davis, L, 2003, *Valuing honeybee pollination*, Centre for International Economics, report prepared for the Rural Industries Research and Development Corporation.

Habitat for species

Description of ecosystem service and users

Forests in Victorian RFA regions provide habitat for plants and animals and support the maintenance of biodiversity. It is important to capture measures of habitat and biodiversity in an ecosystem accounting framework. Ecosystems have unique intrinsic (non-anthropocentric) value, but we also know that people value the existence of healthy ecosystems, species and biodiversity. Including provision of habitat for species ensures that this is represented and communicated alongside other ecosystem services that are more tangibly used (such as water). Habitat is also strongly linked to some ecosystem services such as opportunities for recreation and tourism, as people may visit a forest to see certain species.

Fauna and flora species have different habitat requirements. They need a place to live and reproduce and need to tolerate changes in the weather as well as flood and fire disturbances. Because of these different needs, species are found in different locations across forest landscapes. Some species have highly specific habitat requirements (such as hollow-dependent arboreal marsupials that are present only in limited parts of mountain and alpine ash forests that support hollow-bearing trees), while other species can thrive in many different habitat types.

Provision of habitat has not been valued in monetary terms for this study. Stated preference techniques are commonly used to estimate existence values and could be used to derive Victorian willingness to pay for the existence of forests (e.g. conservation of habitat and species). These types of studies require careful design and implementation to elicit robust and meaningful results.

Examples of the application of stated preference techniques in the Victorian context include a 2007 study undertaken for the Victorian Environmental Assessment Council.[122] This study found that households in Melbourne and Bairnsdale were willing to pay $1.45 and $3.29 respectively per year for 20 years for a 1,000 hectare increase in area of healthy Murray River Red Gum forest. The same study found that households in Melbourne and Bairnsdale were willing to pay $11.16 and $8.10 respectively per year for 20 years for a 1,000 hectare increase in area of protected rainforest, and 65 cents and 33 cents respectively for a 1,000 hectare increase in area of protected old growth forest. This does not mean that particular communities should bear financial responsibility for habitat conservation, but rather demonstrates that different communities (and people within communities) may place greater value on certain attributes or areas of forests.

Quantification of ecosystem service

While this study does not attempt to value habitat for species in monetary terms (as discussed above), habitat metrics are presented. This analysis draws on the 'range size corrected richness' dataset created as part of the Integrated Biodiversity Values Model (IBVM) developed by the Arthur Rylah Institute. The dataset takes into account the extent and quality of habitat available for 35 terrestrial threatened species that are expected to be acutely affected by timber harvesting. The value of each (75 metre x 75 metre) grid cell is a sum over all species of the proportion of their distribution that is covered by the grid cell. Distributions take forest age into account when the species prefers the architectural elements of older forests, such as hollows.

High values indicate a location that supports multiple species with relatively restricted distributions, or even a single species with an extremely restricted distribution. This provides an indication of areas that

122. URS 2007, *Non-use values of Victorian public land: Case studies of River Red Gum and East Gippsland forests*, report prepared for the Victorian Environmental Assessment Council.

may provide significant habitat services. For example, the high value area in the south east corner of the Central Highlands RFA region (see Figure 37) is the Baw Baw plateau. The distribution of the critically endangered Baw Baw frog (*Philoria frosti*), which is restricted entirely to this small area, generates its high value. The Baw Baw plateau is also thought to be relatively important habitat for the Leadbeater's possum (*Gymnobelideus leadbeateri*), Serpent Heath (*Richea victoriana*) and the Baw Baw berry (*Wittsteinia vacciniacea*).

Differences can be seen across RFA regions. On average, woody vegetation (forests) in the Central Highlands and East Gippsland RFA regions provide high proportions of habitat per spatial unit for threatened species that are acutely affected by timber harvesting, compared to the West. On average, forests in the Gippsland and North East RFA regions provide high proportions of habitat per spatial unit compared to the West, but low proportions compared to the Central Highlands and East Gippsland (see Figure 37 and Table 43). Difference can also be seen across different tenure types. On average, forests in national parks and state forests provides high proportions of habitat for species per spatial unit, compared to private land and other public land (see Table 44).

On average, plantation tenure areas provide low proportions of habitat for species per spatial unit, compared to national parks and state forests.[123] However, in the Gippsland RFA region, plantation tenure areas provide a high proportion of habitat for species per spatial unit, compared to other RFA regions (see Table 44). This may point to the importance of remnant woody vegetation in plantation tenure areas in providing habitat for species in the Gippsland RFA region.

It should be noted that habitat distribution models (HDMs) underpin this dataset and analysis and, while representing the best available information, it is likely that true species distributions differ from the HDM predictions. Differences are more likely for declining species and those with limited distributions. Species distributions also respond dynamically to disturbances such as fire and timber harvesting.

The IBVM 'range size corrected richness' dataset is just one approach to reporting on provision of habitat for species, and it brings species range and species richness together in one metric. While this is useful for some reporting purposes, these aspects (range and richness) could also be reported separately in an accounting framework.

123. Note that in this analysis plantation tenure areas are not plantation forest, but rather native woody vegetation on plantation tenure land.

Figure 37 Range weighted species richness across Victoria

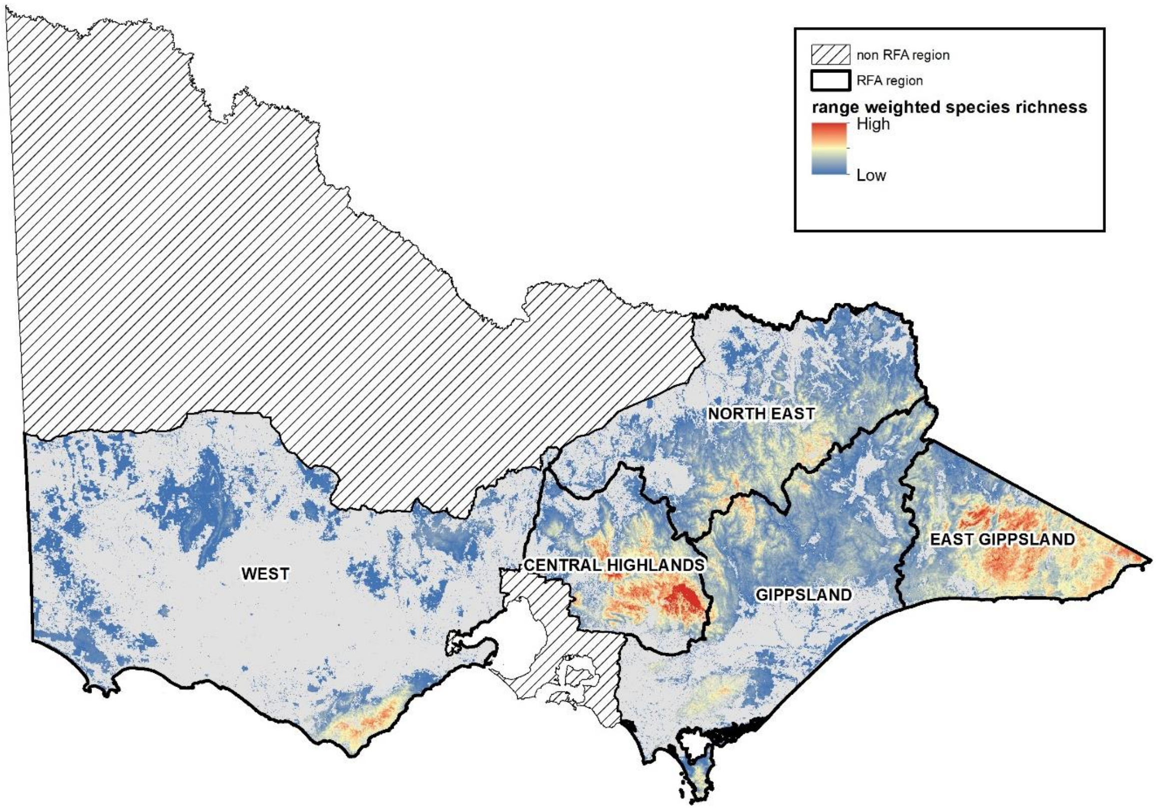


Table 43 Percent of a species' habitat occurring per 10,000 km² of forest (woody vegetation) in each RFA region

RFA region	Area of woody vegetation (10,000 km²)	% of species habitat occurring per 10,000 km² (on average)
Central Highlands	0.76	25
East Gippsland	1.12	24
Gippsland	1.59	13
North East	1.37	13
West	1.24	6

The data in this table can be interpreted as: "On average, 24 per cent of a species' habitat occurs per 10,000 km² of woody vegetation in East Gippsland."

Table 44 Percent of a species' habitat occurring per 10,000 km^2 of forest (woody vegetation) in each RFA region by tenure

RFA region	Tenure	Area of woody vegetation (10,000 km^2)	% of species habitat occurring per 10,000 km^2 (on average)
Central Highlands	National park	0.19	31
	State forest	0.39	28
	Plantation[a]	0.00	15
	Other public land	0.02	11
	Private land	0.16	11
East Gippsland	National park	0.46	24
	State forest	0.58	26
	Other public land	0.01	15
	Private land	0.08	15
Gippsland	National park	0.52	14
	State forest	0.81	13
	Plantation[a]	0.03	21
	Other public land	0.02	6
	Private land	0.21	8
North East	National park	0.40	16
	State forest	0.72	14
	Plantation[a]	0.01	6
	Other public land	0.02	4
	Private land	0.21	4
West	National park	0.50	8
	State forest	0.30	5
	Plantation[a]	0.01	7
	Other public land	0.04	3
	Private land	0.39	4

The data in this table can be interpreted as: "On average, 31 per cent of a species' habitat occurs per 10,000 km^2 of national park in the Central Highlands."

(a) Plantation is the area of woody vegetation on plantation *tenure* land, once area of plantation forest has been removed. That is, it represents areas of native vegetation remaining in plantations.

Air filtration

Description of ecosystem service and users

Forests in Victorian RFA regions provide an air filtration service. Trees and other native vegetation help filter a number of air pollutants. They intercept and trap airborne particles and absorb other pollutants such as carbon monoxide, sulfur dioxide, and nitrogen dioxide. This ecosystem service is used by communities who benefit from improved air quality through improved amenity and health outcomes.

The links between air quality, population exposure and health are an increasing focus for research and policy development, and there is an increasing body of evidence demonstrating that air pollution is associated with adverse health effects. The strongest evidence relates to premature mortality and effects on the cardiovascular and respiratory systems.[124]

It should be recognised that forest ecosystems also emit air pollutants in the form of volatile organic compounds from eucalypt vegetation, which can increase the level of ozone and particle pollution, and smoke from bushfires and planned burns. Disservices from the environment to the economy are generally not included in ecosystem accounting frameworks, although this continues to be an area of research and discussion.[125] Ecosystem disservices may impact on the condition of ecosystem assets, which in turn affects flows of ecosystem services from these assets. For example, particle pollution can adversely impact the health of ecosystems, as well as human health.

The quantity of pollutants filtered by forest ecosystems and the value of this ecosystem service have not been estimated for this study due to the absence of data. While estimates of the quantity of certain pollutants emitted to the atmosphere are available for Victoria,[126] data on the quantity of pollutants removed from the atmosphere by forests is not available.

Higher levels of pollution often occur in more densely populated urban areas, such as Melbourne, where there are significant emissions from motor vehicles, industrial facilities and domestic activities. The magnitude of air quality regulation services provided by forests is dependent on a combination of complex factors including topographic and airshed (atmospheric) characteristics; the amount, type and location of vegetation in relation to pollution sources and populations; and population density. There are often greater aggregate benefits to people in higher density areas where more people benefit from improvements in air quality. However, forest ecosystems in less populated areas may provide important localised benefits to communities.

The ecosystem service of air filtration could be valued based on avoided health impacts, such as the avoided cost of medical treatment. This would require information on the quantity of pollutants filtered by forests and the avoided health impacts associated with this.

124. Environment Protection Authority 2018, *Air pollution in Victoria: A summary of the state of knowledge*, State of Victoria, Melbourne.

125. See discussion in Barton, DN, Caparrós, A, Conner, N, Edens, B, Piaggio, M, Turpie, J 2019, *Discussion paper 5.1: Defining exchange and welfare values, articulating institutional arrangements and establishing the valuation context for ecosystem accounting*, paper drafted as input into the revision of the System on Environmental-Economic Accounting 2012 – Experimental Ecosystem Accounting, version of 25 July 2019, p. 85.

126. The Commonwealth Department of the Environment and Energy publishes National Pollution Inventory data which includes emissions to the atmosphere.

Pest and disease control

Description of ecosystem service and users

Forest in Victorian RFA regions provide the ecosystem service of pest and disease control. Ecosystems support the control of pests and diseases due to genetic variation of plants and animals making them less disease-prone and by providing habitats for species that help control pests (natural predators).

Forests can be degraded by pests and disease, which can reduce the extent or condition of forest ecosystems. However, forests also provide habitat for native species (such as birds and bats) that are major predators of insects and can help in controlling pests. The agriculture industry is a user of this ecosystem service, which provides benefits to producers and consumers of agricultural products that would otherwise be impacted by pests. CSIRO research has found that native vegetation provides habitat for species that are natural enemies of insects and have the potential to suppress pest populations in crops.[127]

The Victorian parks network, which contains half of the state's public forests, provides suitable habitats for 20 species of insectivorous bats and more than 120 species of insectivorous birds, as well as many other insect eating species such as spiders, reptiles and mammals.[128] These native species consume millions of insects each year and act as natural controllers of pests and diseases on agricultural land to improve productivity. For example, bats can significantly reduce insects that are harmful to crops and it is estimated that a group of a thousand bats can eat 5 kilograms or more of insects per night. The parks network also provides habitats for 25 native birds of prey, which can contribute to the management of overabundant pest species such as rabbits and mice.

While many native birds, bats and other species provide a service that benefits agriculture, some species (such as galahs, corellas, flying foxes and kangaroos) can be considered a pest. Disservices from the environment to the economy are generally not included in ecosystem accounting frameworks, however they are important considerations for policy and management decision-making.

There is a lack of Australian or Victorian studies that could be used to quantify and value pest and disease control services. Natural pest and disease control could be valued based on the costs avoided by having predators (such as birds or bats) suppress pests instead of pesticides. The proportion of birds or bats for which forests provide a suitable habitat could be used to attribute the total benefits from this ecosystem service to forests.

International examples include a 2011 study that estimated the value of bats to the north American agricultural industry at US$23 billion per year, with a range of US$3.7 billion to US$53 billion per year.[129] Another study estimated the total value of insects in providing ecological services in the United States to be at least US$57 billion per year (including US$0.38 billion for dung burial, US$3.07 billion for pollination, US$4.49 billion for pest control of native herbivores and US$49.96 billion for recreation).[130]

127. See Gagic, V, Paull, C & Schellhorn, N 2018, 'Ecosystem service of biological pest control in Australia: the role of non-crop habitats within landscapes', *Austral Entomology*, volume 57, issue 2, pp. 194-206; Bianchi, F, Schellhorn, N & Cunningham, S 2013, 'Habitat functionality for the ecosystem service of pest control: reproduction and feeding site of pests and natural enemies', *Agricultural and Forest Entomology*, volume 15, issue 1, pp. 12-23.

128. Department of Environment, Land, Water and Planning and Parks Victoria 2015, *Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne. p. 100.

129. Boyle, J, Cryan P, McCracken G & Kunz, T 2011, 'Economic importance of bats in agriculture', *Science*, volume 332, pp. 41-42.

130. Losey, J & Vaughan, M 2006, 'The economic value of ecological services provided by insects', *BioScience*, volume 56, issue 4, pp. 311-323.

Cultural services

Opportunities for recreation and tourism

Description of ecosystem service and users

Forests in Victorian RFA regions provide diverse opportunities for recreation and sightseeing. The user of this ecosystem service is the Victorian community (households) as well as interstate and international visitors. The tourism industry may also directly use this ecosystem service as an input to tour operations in parks and state forests.

People visit forests for a wide range of experiences that are supported or enhanced by the environmental amenities that forests provide. That is, forest ecosystems contribute to the benefit visitors receive along with non-environmental amenities such as walking tracks or picnic facilities.

People gain benefits from visiting forests, such as enjoyment and improved health and wellbeing. Enjoyment benefits include escaping the urban environment, experiencing nature, culture and heritage, experiencing adventure and self-reliance, having fun, socialising with friends and family, or relaxing and unwinding. There is a large and increasing body of evidence showing that contact with nature and forests provides a wide range of physical and mental health benefits, both from physical activity and passive experience of forests.

Activities undertaken in forests in Victoria (including parks and state forests) include:

- Walking
- Sightseeing
- Birdwatching
- Photography
- Picnicking
- Camping
- Mountain biking
- Trail bike (motorcycle) riding
- Four-wheel driving
- Hunting and fishing

Quantification of ecosystem service

The number of visits to forests can be used as a measure of the ecosystem service. While data on visits to forest ecosystems is not specifically available, data is available on visits to parks and state forests, which can be extrapolated to estimate the number of visits to public forests in RFA regions.

There were over 42.3 million visits to state and national parks across Victoria in 2016-17.[131] This includes
25.52 million visits from Melbourne residents, 14.31 million visits from regional Victorians, 1.4 million from interstate travellers and 660,000 from international visitors. Figure 38 shows the number of annual visits to different parks across Victoria. (Note this map is based on visitor estimates from 2014). It shows the high number of visits to forested parks within RFA regions. There are over a million visits each per year to the Grampians National Park and the Great Otway National Park in the West RFA region, as well as to the Alpine National Park in the east of the state.

131. Parks Victoria visitor number monitor 2016-17.

There were 6.7 million visits to state forests in the six months between February and July 2019.[132] Doubling this gives an estimate of 13.3 million visits per year. This may be a conservative estimate of annual visits as it does not include summer months of December and January which are likely to have a high number of visits. Gippsland (roughly aligning with the Gippsland and East Gippsland RFA regions) was the most popular DELWP region for state forest visitation, followed by Hume (roughly aligning with the North East RFA region) and Grampians (which is included in the West RFA region).

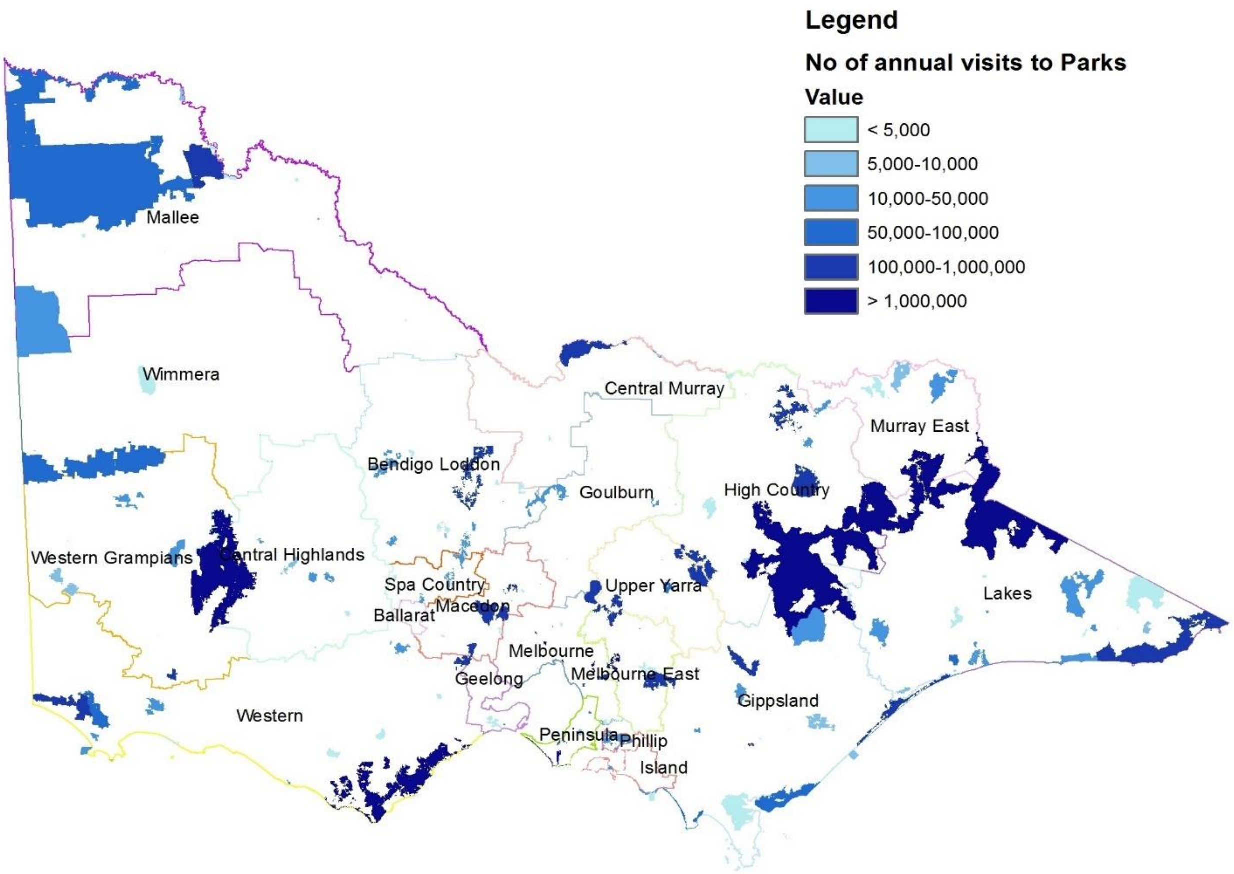
The number of visits to parks is significantly higher than to state forests. This is likely due to high visitation to iconic parks in close proximity to Melbourne such as the Dandenong Ranges National Park, and international tourism to the Port Campbell National Park on the Great Ocean Road. It should be noted that visitation estimates for parks and state forests have been derived from different studies and may not be directly comparable.

The total number of visits to parks and state forests in Victoria (around 55.6 million) can be disaggregated based on the area of parks and state forests that is forest within RFA regions (53 per cent of parks and 86 per cent of state forests). This gives an indicative estimate of the number of visits to forests in RFA regions of 34.1 million visits per year. It should be noted that this top-down disaggregation based on area does not account for differences in visitation to different parts of the state (i.e. that some areas of parks and state forests are more heavily visited than others). For this reason, further disaggregation to individual RFA regions has not been undertaken.

The number of visits to forest on private land is unknown but expected to be minimal relative to parks and state forests, as access to forest on private land is generally restricted and there are limited visitation opportunities. However, there would be some visitation associated with private properties such as eco-lodges and camps.

132. Quantum Market Research 2019, *Understanding state forest visitation and tourism*, report prepared for the Department of Environment, Land, Water and Planning.

Figure 38 Annual visits to parks



Source: DELWP and Parks Victoria 2015

Valuation of ecosystem service

Opportunities for recreation can be valued using an indirect market price approach, based on observed purchases of goods and services that are directly related to visiting and recreating in forests.[133] The benefit people obtain from visiting a forest can be estimated by understanding the demand for associated goods and services. The more people use equipment to undertake activities (e.g. hiking and camping gear) and the more people spend time and energy to travel to a location, the higher the value of the recreation service provided by that area forest.

In Victoria, there are fees to access facilities in some forests. However, fees are typically charged to cover the cost of maintenance and operations and do not represent the value contributed by the ecosystem. These fees are regulated and are not determined by the market.

133. This approach is outlined in Barton, DN, Obst, C, Day, B, Caparros, A, Dadvand, P, Fenichel, E, Havinga, I, Hein, L, McPhearson, T, Randrup, T & Zulian, G 2019, 'Discussion paper 10: Recreation services from ecosystems', paper submitted to the Expert Meeting on Advancing the Measurement of Ecosystem Services for Ecosystem Accounting, New York, 22-24 January 2019 and subsequently revised, version of 25 March 2019.

This analysis draws on two studies undertaken to estimate the tourism expenditure associated with visitation of parks and state forests. It should be noted that these studies were undertaken at different times and using slightly different methodologies. However, they are broadly comparable and represent the best available information.

In 2014, it was estimated that tourism associated with Victorian parks directly contributed $491 million to gross state product in 2010-11 (or $579 million in 2018 dollars).[134] In 2019, it was estimated that tourism associated with state forests directly contributed $345.5 million to gross state product between February and July 2019. This figure is doubled to provide a 12-month estimate of $691 million, although this may be a conservative estimate as tourism may be greater over the summer months.

These estimates are for tourism associated with parks and state forests across the whole of Victoria. Weighted to the proportion of parks and state forests that is forest within RFA regions, the estimated contribution of tourism associated with public forests in RFA regions is $905 million. This gives an indicative estimate of the value of this ecosystem service. It should be noted that this top-down disaggregation based on area does not account for differences in tourism to different parts of the state. For this reason, further disaggregation to individual RFA regions has not been undertaken.

This estimate may overstate the direct contribution of the ecosystem, as people gain value from infrastructure that enhances tourism and recreational experiences such as signage, picnic and camping facilities and walking and mountain biking trails. The ecosystem and built assets function together to deliver value in the economy and community.

Health and wellbeing

This assessment of recreation in parks and state forests does not account for the health and wellbeing benefits people gain from recreating and spending time in forests, which may be additional to the value estimated above.

For example, in a 2015 study of Victoria's parks network, it was estimated that over 750,000 people visit state and national parks each year specifically to do physical exercise. Based on the avoided healthcare costs and productivity impacts associated with physical activity, the value of health and wellbeing benefits was estimated at $118 million year.[135]

134. Deloitte 2014, *The economic contribution of tourist visitation to Victorian parks: Valuing the tourism services provided by Victorian parks*, report prepared for Parks Victoria, pp. 103-111.

135. Department of Environment, Land, Water and Planning and Parks Victoria 2015, *Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne, p. 119.

Opportunities for social and community connection

Description of ecosystem service

In addition to providing opportunities for recreation and sightseeing, forests provide opportunities for social and community connection and contribution. Forests in Victorian RFA regions provide opportunities for people to connect and participate in social and community activities. This is similar to (and may overlap with) opportunities for recreation, but specifically relates to people forming social connections or contributing to the community. These experiences are supported or enhanced by the environmental amenities that forests provide, although it is difficult to isolate the contribution of the ecosystem itself.

One indicator of this ecosystem service is the time people spend volunteering or participating in community activities in forests. People may gain physical and mental health benefits from participating in these types of activities, as well as a sense of satisfaction and enjoyment from contributing to the environment and community. Volunteering and community participation is also an important avenue through which land managers and the community collaborate in the conservation and management of state forests and parks.

The quality of data on volunteering and community activities varies, with good data in some areas and poor data in others. Across Victoria, an estimated 100,000 people participate in environmental volunteering each year.[136] Formal volunteering programs that encompass forest areas on public and private land include:

- Committees of Management – there are approximately 1,200 volunteer committees of management that work on behalf of the Minister for Energy, Environment and Climate Change to manage 1,500 crown land reserves across Victoria.
- Landcare – Victoria has around 600 Landcare groups and 64 Landcare networks, and more than 500 other community-based natural resource management groups. Victoria's Landcare and other environmental volunteer groups have around 60,000 members and an additional 45,000 volunteers who contribute their time and energy each year to help care for natural resources. While Landcare has traditionally worked on private land, some groups and networks also work collaboratively with public land managers to undertake projects on public land. Landcare groups cover 52 per cent of the state, including 68 per cent of private land and 21 per cent of public land.
- Land for Wildlife – a government program supporting private landholders or managers who provide habitat for native wildlife on their land. Over 12,500 people contribute to native biodiversity conservation through membership with Land for Wildlife. They are actively involved in protecting habitat or restoring habitats on their own land. Approximately 5,000 properties covering more than 530,000 hectares of private land are currently registered throughout Victoria.
- Trust for Nature – develops conservation covenants to protect native plants and wildlife on private land.
- Recreational user groups – such as four-wheel drive clubs, bushwalkers, mountain bike clubs and shooting associations often work to protect local environments.
- Citizen science – typically involves volunteers collaborating with scientists to enhance knowledge and support management of biodiversity.

136. Department of Environment, Land, Water and Planning 2018, *Victorians volunteering for nature: Environmental volunteering plan*, State of Victoria, Melbourne, p. 9.

Valuing volunteering in Victoria's parks

A 2015 study estimated the value of volunteering in Victoria's parks. Over 210,000 hours are spent volunteering in parks each year, which is equivalent to more than 100 full time employees.[137] Volunteer hours were valued using the opportunity cost of the time that people doing unpaid work could have obtained if they had spent the time in paid work.

Estimates of gross opportunity cost wage rates for volunteers were calculated between 1992 and 2006,[138] based on earlier work by the Australian Bureau of Statistics.[139] The gross opportunity wage rate was estimated at $24.09 per hour in 2006. Adjusting for inflation, the volunteer hours were valued at $6 million per year in 2015.

While this analysis does not isolate the contribution of ecosystems, it likely underestimated the broader benefits of volunteering in parks, as the valuation is limited to financial opportunity cost. The health and community benefits of volunteering in forests and other ecosystems have not been estimated and is a potential area for further research.

137. Parks Victoria, unpublished.

138. Ironmonger, D 2012, *The economic value of volunteering in Victoria*, report prepared for the Victorian Department of Community Development.

139. Australian Bureau of Statistics 2000, *Unpaid work and the Australian Economy*, Commonwealth of Australia, Canberra.

Opportunities for cultural heritage connection

Description of ecosystem service

Forests in Victorian RFA regions encompass landscapes and sites of cultural and historical significance that Victorian, Australian and global communities value as part of their heritage. Forests provide immense value to Traditional Owners and Aboriginal communities, as well as providing heritage value to non-Aboriginal Victorians.

Opportunities for cultural heritage connection are not always provided solely by ecosystems: forest ecosystems combine with other attributes (such as historic structures and artefacts) to deliver benefits in the form of opportunities to connect with culture and heritage. However, forest ecosystems support and enhance connections, allowing place-based experiences rather than preservation in museums or other contexts.

Aboriginal cultural heritage places

In 2017 there were over 12,000 registered Aboriginal cultural heritage places in Victorian public forests and other crown land. This includes 8,138 registered heritage places in parks and conservation reserves, over 1,287 in state forests and 2,712 on other Crown land.[140] The number of registered sites has been increasing over time, with a
5 per cent increase between 2012 and 2017. Common components of places include artefact distribution, scarred trees and hearths.

The value of forests to Traditional Owners and Aboriginal communities is not assessed in this study. Different types of ecosystem services can individually or collectively deliver cultural and economic value to Aboriginal communities. The Victorian Government's forest modernisation program is partnering with Traditional Owners, as the original custodians of Victoria's land and waters, to support and facilitate Traditional Owners to capture information about their values (including tangible and intangible values). Ecosystem accounting is a developing field, and there is potential for cultural values to be incorporated into ecosystem accounting frameworks in Victoria in the future.

Non-Aboriginal cultural heritage places

As of 2017, there were over 3,600 non-Aboriginal heritage components (artefacts that exist at a particular place) at over 1,800 places in state forests and parks and conservation reserves.[141] The most common are components associated with mining and mineral processing with over 1,900 in parks and reserves and 950 in state forests. Forestry and timber industry components are the second most common, with 134 components in parks and reserves and 162 in state forests.

Non-Aboriginal heritage value has previously been estimated for Victoria's parks.[142] Historic heritage is the primary purpose for a significant number of visitors to Victorian parks. This is reflected in the

140. Commissioner for Environmental Sustainability 2018, *State of the Forests 2018*, State of Victoria, Melbourne, p. 187.

141. Commissioner for Environmental Sustainability 2018, *State of the Forests 2018*, State of Victoria, Melbourne, p. 187-188.

142. Department of Environment, Land, Water and Planning and Parks Victoria 2015, *Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne, p. 119.

activities undertaken by visitors to parks, including visiting historic places. In 2009, 55 per cent of the population had visited a heritage place managed by Parks Victoria within the previous 12 months.

A 2009 survey found that 60 per cent of Victorian households would support a yearly charge to maintain heritage places in parks.[143] These survey results have been used to estimate a value range for the maintenance of park-related heritage of $6-23 million per year. These estimates are thought to be a lower bound of the value people place on park-related heritage, as survey participants were only asked their willingness to pay $5, $10 or $20 once, rather than presenting higher bid values iteratively. However, it is also not clear whether the survey was designed to elicit a value for specific or generic historic heritage sites, whether the technical requirements for a robust stated preference method were met, or whether the participating households or respondents were representative of the Victorian population in order to extrapolate the results.

Amenity

Description of ecosystem service

Forests in Victorian RFA regions provide amenity services to surrounding residents, enabling a range of personal and community benefits. This includes both use value from having closer proximity to access forests or gaining health and enjoyment benefits from viewing forests, as well as non-use value from knowing that forest ecosystems are nearby.

In some cases, ecosystems may also generate dis-amenity for surrounding residents. This occurs when there are negative externalities associated with the ecosystem or human interaction with an ecosystem. For example, congestion associated with visitation to a popular area of forest could reduce amenity for surrounding residents,[144] as could an abundance of particular species such as mosquitos. This is why valuation methods, such as hedonic modelling (discussed further below), may generate negative values for ecosystem amenity.

In 2013, there were 38,000 immediate neighbours to national and state parks and 47,000 immediate neighbours to conservation reserves – a total of 85,000 immediate neighbours.[145] Much of the area of parks and conservation reserves adjacent to properties is forested. The number of immediate neighbours to state forests or forest on private land has not been quantified.

The value of amenity benefits from forests has not been estimated for this study. However, potential valuation approaches and related studies are discussed below. This is a potential area for future research.

A common revealed preference technique for valuing amenity is hedonic modelling. Hedonic modelling exploits the fact that some market goods (such as houses) comprise a number of attributes that include non-market elements.[146] Hedonic modelling compares property prices or land value between properties that are in close proximity to an attribute (such as a forest) and those that are not, controlling for other

143. Market Solutions 2009, *Community perception of heritage management in parks*.

144. A 2018 study by Infrastructure Victoria found that there was a negative relationship between house prices and proximity to certain types of parks in Melbourne. The study hypothesised that this is due to congestion or other park-related activities with negative externalities. This suggests there can be trade-offs between the contribution of different cultural ecosystem services such as recreation and amenity. Evangelio, R, Hone, S, Lee, M & Prentice, D 2018, *What makes a locality attractive? Estimates of the amenity value of parks for Victoria*, Technical paper no. 4/18, Infrastructure Victoria, Melbourne, p. 2.

145. Department of Environment, Land, Water and Planning and Parks Victoria 2015, *Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne. p. 113-4.

146. Productivity Commission 2014, *Environmental policy analysis: A guide to non-market valuation*, Commonwealth of Australia, Canberra, p. 28.

factors such as dwelling and property features, transport, schools and other influences on house price. The price difference represents the amenity value of living closer to a forest.

Stated preference techniques (such as willingness to pay studies) could also be used to estimate amenity value. However, revealed preference techniques are generally considered more objective and are preferred where feasible.

Because amenity value is likely to vary by location, Australian (and preferably Victorian) estimates are needed. Several studies have estimated the amenity value of household proximity to parks or forests in Victoria. Although studies have yielded mixed results, on the whole they suggest there is some positive amenity benefit from living near forests.

- A 2013 study estimated that, for lifestyle properties in central Victoria,[147] moving 1 kilometre closer to a national, state or regional park increases the value of a median property by $3,535 per hectare.[148]
- A 2015 study found that, for lifestyle and farming properties in central Victoria, distance to a national, state or regional park has no effect on property value. This finding was unexpected, and the study speculated that this could be because parks are often located on rise, hill, or mountain landforms, and the effect of landform is already incorporated into the model.[149]
- In 2015, a study of the Barmah-Millewa forest found that, for an average property 10 kilometres away from a forest, moving 1 kilometre closer increases the property price by $2,000.[150]
- In 2015, a DELWP and Parks Victoria study estimated the amenity value of Melbourne's urban and peri-urban parks at $326 million to $438 million, or $21 million to $28 million per year. The study also suggested the amenity value associated with the Greater Bendigo National Park could be around $17 million.[151]
- In 2018, an Infrastructure Victoria study found that, in regional areas, proximity to all types of parks has a positive impact on house prices.[152] Although regional, state and national parks (which would contain forests) have less amenity value than community and cultural parks. The average difference in prices between houses close to a park (first percentile distance) to further away (median distance) ranges from $8,000 to $86,000.

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147. Lifestyle properties are defined as rural properties where land use (agriculture) is not the primary source of income for owners. The study area includes the local government areas of Greater Bendigo, Mount Alexander, Hepburn, Macedon Ranges and Mitchel.

148. Polyakov, M, Pannell, DJ, Pandit, R, Tapsuwan, S & Park, G 2013, 'Valuing environmental assets on rural lifestyle properties', *Agricultural and Resource Economics Review*, volume 42, pp. 159-175.

149. Polyakov, M, Pannell, DJ, Pandit, R, Tapsuwan, S & Park, G 2015, 'Capitalized amenity value of native vegetation in a multifunctional rural landscape', *American Journal of Agricultural Economics*, volume 97, pp. 299-314.

150. Tapsuwan, S, Polyakov, M, Bark, R & Nolan, M 2015, 'Valuing the Barmah-Millewa forest and in stream river flows: A spatial heteroscedasticity and autocorrelation consistent (SHAC) approach', *Ecological Economics*, volume 111, pp. 98-105.

151. Department of Environment, Land, Water and Planning and Parks Victoria 2015, *Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne. p. 113-4.

152. Evangelio, R, Hone, S, Lee, M & Prentice, D 2018, *What makes a locality attractive? Estimates of the amenity value of parks for Victoria*, Technical paper no. 4/18, Infrastructure Victoria, Melbourne

Education and knowledge

Description of ecosystem service

Forests in Victorian RFA regions provide unique ecosystems that are inputs to research and education activities. This is used by the education and research sectors, and directly benefits people who visit or study forests for education and research purposes. Victorian, Australian and global communities benefit from education and research outcomes (through progress in knowledge or technology).

Forests provide a wide range of opportunities for research, and the knowledge gained from forests contributes to the broader knowledge of the community about nature, culture and heritage. Land managers, such as DELWP and Parks Victoria, recognise the importance of research in forests to ensure that management is informed by science and evidence.

Forests provide opportunities for schools, tertiary institutions and the community to gain a greater appreciation and understanding of nature, culture and heritage through formal and informal programs. For example, Parks Victoria's Research Partners Program encourages research to be undertaken in parks through collaboration with universities and other research institutions.[153]

A wide range of formal and informal education and interpretation programs are undertaken in forests to inspire and educate visitors about nature, forests, culture and heritage.

Data on education and research is more prevalent for parks than for state forests. On average 215 research permits are issued in parks each year and 183,000 people participate in parks related education programs.[154]

In an assessment of Parks Victoria's Research Partners Program it was determined that each dollar of Parks Victoria research funding resulted in approximately six dollars of leveraged research funding from partners. However, this represents costs of conducting research and not the actual benefits created in society or the economy from the knowledge, materials or technologies obtained from research once they have been adopted. Some of these benefits could include productivity or efficiency gains in the management of native species or development of genetic material for medical research.

The value of education and research benefits from forests has not been estimated for this study. However, potential valuation approaches that could be undertaken in the future include:

- Valuation using the productivity method, based on the long-term impact of research and education in society and the economy. This would greatly depend on the type of research being undertaken and may require a selection of case studies.
- The financial cost to individuals or institutions of undertaking research could be used as a lower bound estimate of the benefits expected by research and education partners from access to state forests and parks. Net financial income to land managers (DELWP and Parks Victoria) from research activity could also be used, however there is generally no fee for the issue of research permits.

153. See https://parkweb.vic.gov.au/park-management/environment/research-and-scientific-management/research/research-partners-program

154. Department of Environment, Land, Water and Planning and Parks Victoria 2015, *Valuing Victoria's parks: Accounting for ecosystems and valuing their benefits*, State of Victoria, Melbourne, p. 117.

Appendix B: Assessment of abiotic services from forest areas

Abiotic services

Ecosystem services do not represent the complete set of flows from the environment that contribute to economic and other human activity.[155] Other flows include the extraction of mineral and energy resources, harnessing of energy from the sun for growing crops and use as a renewable energy source, and the movement of wind and tides which can be captured to serve as sources of energy. The environment provides the space in which economic and other human activity takes place and the provision of space can be conceptualised as a flow.[156] Collectively, these other flows from the environment are referred to as abiotic services.

Information on abiotic services is often presented alongside ecosystem services. This is useful because ecosystem accounting can be used to organise information for assessing alternative uses of land, and often there are trade-offs between combinations of ecosystem and abiotic services that stem from alternative land uses.

Mineral resources is a key abiotic service that flows from within forest areas in Victoria.

Mineral resources

Description of service

In Victoria, forest areas often surround mineral resource deposits. Consequently, forests are important for industry or public access to mineral resources. The users of this abiotic service are the mining industry and households undertaking recreational prospecting and fossicking.

There is also a strong link between mineral resources and cultural heritage. Of non-Aboriginal cultural heritage artefacts in forests, mining and mineral processing artefacts are the most common, with almost 3,000 artefacts within parks and state forests.[157]

Quantification of service

Ideally, this service would be measured as the quantity of mineral resources extracted from areas of land within forests. However, this data is not readily available and cannot be reliably estimated for forest areas in RFA regions.

In the absence of information on mineral extraction, opportunities for mining within forest areas in RFA regions has been mapped using spatial data on mining licenses. There are 227 mining licenses across Victoria,[158] covering around 65,000 hectares – see Table 45. Just under half (44 per cent) are within RFA regions and
37 per cent are within, or intersect with, forest areas in RFA regions. The Gippsland RFA region has the highest number of licenses that intersect with forests (35 licenses), covering over 6,600 hectares of

155. United Nations 2014, *System of environmental-economic accounting 2012: Experimental ecosystem accounting*, United Nations, New York, pp. 44.

156. United Nations 2014, *System of environmental-economic accounting 2012: Experimental ecosystem accounting*, United Nations, New York, pp. 44-45.

157. Commissioner for Environmental Sustainability 2018, *State of the Forests 2018*, State of Victoria, Melbourne, p. 188.

158. The purpose of a mining licence is to undertake mining and activities leading to or ancillary to mining. While exploration can be undertaken on a mining licence, "exploration only" will only be permitted in very limited circumstances. These circumstances include a temporary mine closure, during which further exploration is undertaken to identify mineral resources required to recommence mining.

forest. The West RFA region has 27 licenses that intersect with forest, covering over 6,300 hectares of forest.

Recreational prospecting and fossicking is permitted in state forests and in certain parks. Recreational prospectors and fossickers must purchase a Miner's Right, which allows the holder the right to remove and keep minerals discovered on Crown land or private land (where the landowner has given permission).

Table 45 Mining licenses in Victoria

RFA region	Total number of licenses	Total area licensed (ha)	Number of licenses that intersect with forests	Area of forest licensed (ha)	% total licenses that intersect with forests	% total area licensed that is in forests
Central Highlands	10	1,031	9	1,009	90	98
East Gippsland	1	2	1	2	100	100
Gippsland	43	20,820	35	6,723	81	32
North East	14	720	13	642	93	89
West	33	15,177	27	6,364	82	42
Non-RFA	126	27,027	70	4,866	56	18
Total RFA	101	37,749	85	14,738	84	39
Total Victoria	227	64,776	155	19,604	68	30

Source: Department of Jobs, Precincts and Regions

Appendix C: Classification of ecosystem and abiotic services

Table 46 outlines ecosystem and abiotic services included in this study and how they relate to the Common International Classification of Ecosystem Services (CICES). Services we selected for inclusion in this study based on review of existing forest ecosystem accounting studies in Victoria and other jurisdictions, relevance to Victoria, and correlation with CICES.

Table 46 Classification of ecosystem and abiotic services under CICES

Service included in this study	CICES version 5.1			
	Section	Division	Group	Class
Ecosystem services				
Water provision	Provisioning	Water	Surface water used for nutrition, materials or energy	Surface water for drinking
				Surface water used as a material (non-drinking purposes)
				Freshwater surface water used as an energy source
			Ground water used for nutrition, materials or energy	Ground (and subsurface) water for drinking
				Ground (and subsurface) water used as a material (non-drinking purposes)
				Ground (and subsurface) water used as an energy source
Biomass for timber	Provisioning	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials)
			Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Fibres and other materials from wild plants for direct use or processing (excluding genetic materials)
Biomass for firewood	Provisioning	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Cultivated plants (including fungi, algae) grown as a source of energy
			Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy
Honey	Provisioning	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Cultivated plants (including fungi, algae) grown as a source of energy
			Wild plants (terrestrial and aquatic) for	Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy

Service included in this study	CICES version 5.1 Section	Division	Group	Class
			nutrition, materials or energy	
Fodder	Provisioning	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Cultivated plants (including fungi, algae) grown as a source of energy
			Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy
Water flow regulation	Regulation and maintenance	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Hydrological cycle and water flow regulation (including flood control and coastal protection)
Soil retention (erosion prevention)	Regulation and maintenance	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Control of erosion rates
Carbon sequestration and storage	Regulation and maintenance	Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans
Pollination	Regulation and maintenance	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination (or 'gamete' dispersal in a marine context)
Habitats for species	Regulation and maintenance	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats (including gene pool protection)
Air filtration	Regulation and maintenance	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals
Pest and disease control	Regulation and maintenance	Regulation of physical, chemical, biological conditions	Pest and disease control	Pest control (including invasive species)
Recreation and tourism, health and wellbeing	Cultural	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions
				Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions
Social and community connection	Cultural	Direct, in-situ and outdoor interactions with living systems that depend on presence in	Physical and experiential interactions with natural environment	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions

Service included in this study	CICES version 5.1			
	Section	Division	Group	Class
		the environmental setting		
Cultural heritage connection	Cultural	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that are resonant in terms of culture or heritage
Amenity	Cultural	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable aesthetic experiences
Education and knowledge	Cultural	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Intellectual and representative interactions with natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge
				Characteristics of living systems that enable education and training
Abiotic services				
Minerals	Provisioning	Non-aqueous natural abiotic ecosystem outputs	Mineral substances used for nutrition, materials or energy	Mineral substances used for material purposes
				Mineral substances used as an energy source

Appendix D: Technical summary of biophysical modelling and spatial data analysis

This appendix outlines the biophysical modelling and spatial data analysis approaches undertaken and datasets used to deliver this study of ecosystem services from forests in Victorian RFA regions. Only the services that required biophysical modelling and/or spatial analysis are detailed in this appendix.

Background

The objective of the biophysical modelling and spatial data analysis undertaken was to provide collated data by either RFA region, land tenure, land cover class or catchment type which then enabled quantification and valuation of ecosystem services to be undertaken.

The ecosystem services that required biophysical modelling and/or spatial data analysis, the software used to produce the output and the output generated are detailed in Table 47.

Table 47 Ecosystem and abiotic services requiring biophysical modelling and/or spatial data analysis, dataset and software utilised and output generated

Service	Spatial and temporal datasets used, file name and source	Software used	Raster or vector analysis	Output generated
Water provision	- Designated Water Supply Catchments, PWSC100 (CSDL) - Melbourne Water Catchments (Melbourne Water) - Public Land Management, PLM25 (CSDL) - Sustainable Diversion Limit catchments, SDL_catch (CSDL) - Ecological Vegetation Class, NV1750_EVC (CSDL) - Regional Forest Agreement regions, RFA100 (CSDL) - Forest Extent, Forest_mask_13 (VFMP) - Victorian Digital Elevation Model, DEM25 (CSDL) - Victorian Water Storages (CSDL) - Patched Point Climate Data (SILO) - Victorian Landsystems, Landsystem250 (CSDL) - Water Trading Zones for Victorian Declared Water Systems (Victorian Water Register)	BioSim, EnSym and ArcGIS	Raster	Average annual and annual recharge, surface runoff and lateral sub-surface flow ML/ha (2008-2018) per RFA region, catchment zone, tenure and land cover class.
Biomass for timber	- Victorian Plantation, VMVEG_plantation (CSDL) - Regional Forest Agreement regions, RFA100 (CSDL) - Forest Extent, Forest_mask_13 (VFMP) - Public Land Management, PLM25 (CSDL)	ArcGIS	Vector	Area (ha) of mapped plantation and plantation tenure per RFA region, tenure and land cover class.
Fodder	- Public Land Management, PLM25 (CSDL) - Regional Forest Agreement regions, RFA100 (CSDL) - Forest Extent, Forest_mask_13 (VFMP) - Ecological Vegetation Class, NV1750_EVC (CSDL)	ArcGIS	Vector	Area (ha) of agricultural licensed/leased land per RFA region and license/lease type.
Minerals	- Current Mining Licences and Leases, MIN (CSDL) - Public Land Management, PLM25, (CSDL) - Regional Forest Agreement regions, RFA100 (CSDL) - Forest Extent, Forest_mask_13 (VFMP)	ArcGIS	Vector	Area (ha) and number (count) of mining leases per RFA region and tenure class.

Service	Spatial and temporal datasets used, file name and source	Software used	Raster or vector analysis	Output generated
	- Ecological Vegetation Class, NV1750_EVC (CSDL)			
Soil retention (erosion prevention)	- Designated Water Supply Catchments, PWSC100 (CSDL) - Melbourne Water Catchments (Melbourne Water) - Public Land Management, PLM25 (CSDL). - Sustainable diversion limit catchments, SDL_catch (CSDL) - Ecological Vegetation Class, NV1750_EVC (CSDL) - Regional Forest Agreement regions, RFA100 (CSDL) - Soil and Landscape Grid National Soil Attribute Maps - Bulk Density, (CSIRO) - Patched Point Climate Data (SILO) - Victorian Landsystems, Landsystem250 (CSDL)	BioSim, EnSym and ArcGIS	Raster	Gross and net annual erosion (m^3 and t) per RFA region, PWSC and catchment zone (2008-2018).
Water flow regulation (flood mitigation)	- Public Land Management, PLM25 (CSDL) - Ecological Vegetation Class, NV1750_EVC (CSDL) - Regional Forest Agreement regions, RFA100 (CSDL) - Forest Extent, Forest_mask_13 (VFMP) - Patched Point Climate Data (SILO) - Victorian Land-systems, Landsystem250 (CSDL) - Streamflow data Wangaratta gauge, 403200.csv (Victorian Water Monitoring Data Portal) - Victorian Digital Elevation Model, DEM25 (CSDL) - Locality Boundaries (CSDL) - Victorian Landuse Information System (CSDL) - 1 in 100 Year Flood Extent (CSDL)	BioSim, EnSym and ArcGIS	Raster	Daily stage heights (m) and flow (ML) of the Ovens River at the Wangaratta gauge (#403200) for current land use and counterfactual scenarios (2008-2018). Average annual and annual recharge, surface runoff and lateral sub-surface flow ML/ha (2008-2018) per RFA region, and catchment zone for current land cover and counterfactual land covers (pasture & bare earth). Number of localities benefiting from water flow regulation services.
Carbon sequestration and storage	- Above Ground Forest Biomass, Forest AGB (VFMP, Landfor) - Public Land Management, PLM25 (CSDL) - Regional Forest Agreement regions, RFA100 (CSDL)	EnSym and ArcGIS	Raster	Annual above ground biomass and carbon (t/ha) per RFA region, tenure and land cover classes (1980-2017).

Service	Spatial and temporal datasets used, file name and source	Software used	Raster or vector analysis	Output generated
	- Lastlog25 (CSDL) - Fire_History (CSDL)			Annual change in above ground biomass and carbon (t/ha) per RFA region and tenure (2008-2018) and losses classified as bushfire, timber harvesting or other.
Honey and pollination	- Victorian apiary sites, Apiary (CSDL) - Regional Forestry Agreement regions, RFA100 (CSDL) - Public Land Management, PLM25 (CSDL)	ArcGIS	Vector	Number of apiary sites (count) and average distance from apiary site to forested area (m) per RFA region, and tenure class.
Habitat for species	- Range Weighted Species Richness, 01_RangeWeightedSpeciesRichness_w_quoll.tif (IBVM) - Public Land Management, PLM25 (CSDL) - Regional Forest Agreement regions, RFA100 (CSDL) - Ecological Vegetation Class, NV1750_EVCBCS (CSDL) - Public Land Management, PLM25 (CSDL)	EnSym and ArcGIS	Raster	Range weighted species richness and bioregional condition score per RFA region and land tenure class.
Forest extent and condition	- Native Vegetation Regulation Condition (CSDL) - F_cover_09_2013 (VFMP) - F_cover_13_2018 (VFMP)	Ensym	Raster	Area weighted vegetation condition score per RFA region and tenure class. Forest extent per RFA region, tenure and landcover 2013 and 2018.

CSDL = DELWP Corporate Spatial Data Library
CSIRO = Commonwealth Scientific and Industrial Research Organisation
EVC = Ecological vegetation class
IBVM = DELWP Integrated Biodiversity Values Model
SILO = Database of Australian climate data hosted by the Queensland Department of Environment and Science
VFMP = DELWP Victorian Forest Monitoring Program

General descriptions of models and datasets

Forest extent

Victorian Forest Monitoring Program (VFMP) baseline forest extent data was used to define the extent of forested areas for all ecosystem services assessed spatially, bar the assessment of habitat provision which uses a separate woody vegetation extent dataset developed as part of the Integrated Biodiversity Values Model (IBVM) which was produced by the Arthur Rylah Institute.

Areas on public land mapped as shrubland, grassland or wetland by EVC group classification, were also included in the assessment, knowing they were likely areas of native vegetation albeit not 'forested' vegetation, that were still capable of providing ecosystem services.

EVC data was not used to define forest extent, it was used to define forest class information to the VFMP forest extent data only.

Tenure

For Crown land areas, data is provided from the PLM25 dataset and classified using the MMTGEN field. The following field attributes have been aggregated for clearer reporting:

- Commonwealth Land, Other Public Land, Not Classified or unattributed = Other public land
- Other Conservation Reserves & National Parks Act and Nature Conservation Reserves = National park

Tenure classification is therefore reported as:

- National park
- State forest
- Plantation (note this is plantation tenure on crown land, many parts of this tenure type support native vegetation, road infrastructure and fallow areas not necessarily planted to plantation timber)
- Other public land
- Private land

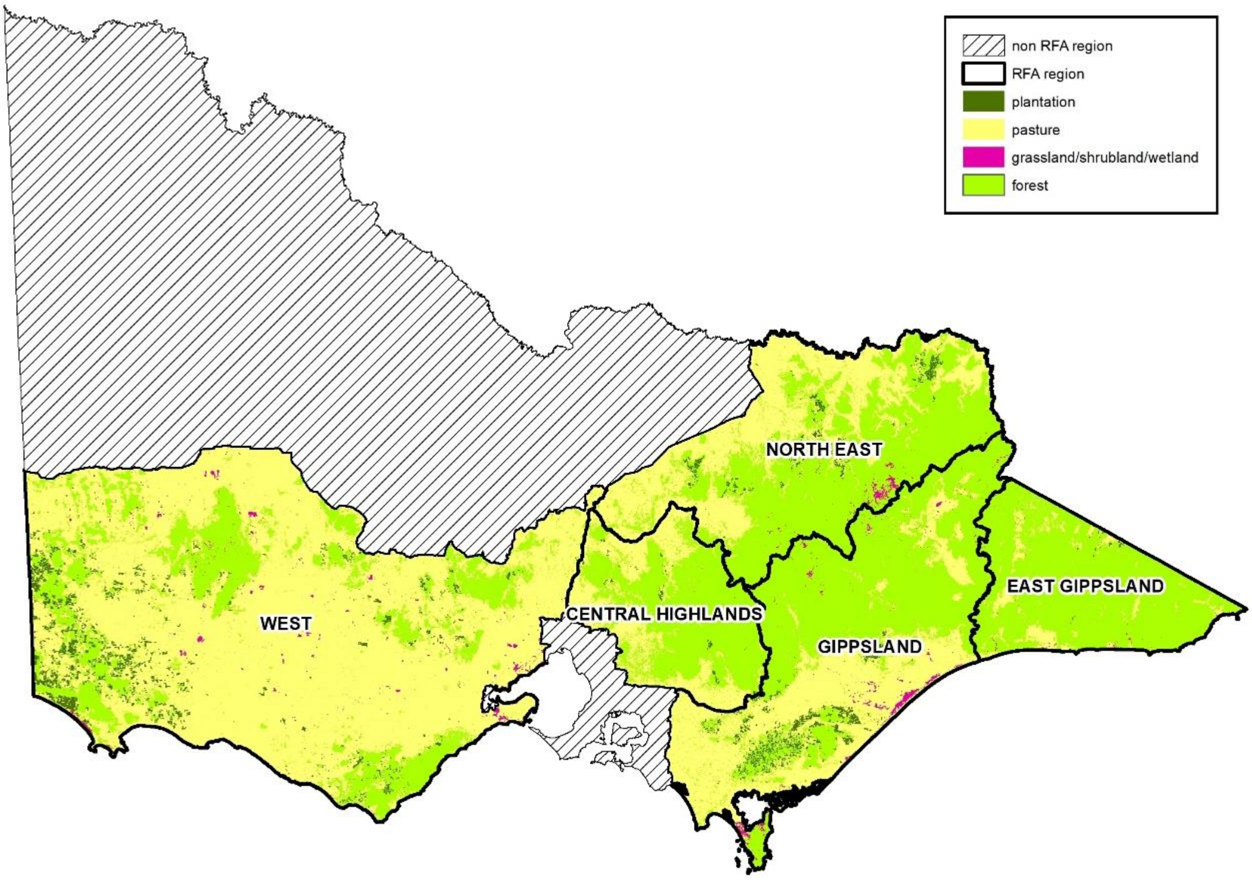
Land cover mapping

A suite of aggregated data was generalised to form a customised land cover map for this project. The whole state of Victoria was divided into the following four broad land cover classifications (refer to Figure 39).

- Forest – forest extent mapping from VFMP determined forested areas, the 'EVC1750' dataset then disaggregated the forest areas into detailed forest types.
- Grassland/shrubland/wetland – for public land areas based on EVC group classification.
- Plantation – mapped plantation areas using the 'VMVEG_plantation' dataset that were coincident with the VFMP forest extent mapping were designated as plantation.
- Pasture – all other areas are assumed to be pasture/cropping.

Although this methodology excludes land uses such as urban, industrial and roading, for the scale at which this assessment was undertaken it was deemed that including such land uses would have added extra complexity to the model and lengthened the model run times whilst not contributing any further clarity to the required output, that being the quantification of hydrological forest ecosystem services.

Figure 39 Aggregated land cover mapping classes



EnSym

EnSym is a modular software platform that facilitates the use of a suite of environmental modelling tools. It enables easy and rapid evaluation of environmental outcomes due to changes in land management and climatic conditions. It contains a number of toolboxes that deal with different aspects of the environment including land based biophysical process, groundwater dynamics, spatial and contextual connectivity and finally a set of tools for systematic spatial and temporal reporting. EnSym has been developed by the Victorian Government.

BioSim

BioSim is the biophysical modelling toolbox of EnSym, designed to simulate all major biophysical components. BioSim simulates daily soil/water/plant interactions, overland water flow process, soil loss and carbon sequestration. BioSim can be applied to any combination of soil type, climate, topography and land practice. BioSim has been developed and used by DELWP and preceding departments since 2000.[159]

159. Beverly, C 2007, *Technical manual – models of the catchment analysis tool*, Department of Sustainability and Environment, State of Victoria, Melbourne.

Details, limitations and assumptions of modelling approach and spatial data analysis

Water provision

Catchment water yield is defined as the quantity of water derived from a unit area of watershed. For this project water yield is reported as available megalitres of flow per day from a given water catchment. Catchment water yield has been modelled using the BioSim model within the EnSym modelling framework. Modelled daily surface runoff, lateral subsurface flow and a proportion of recharge have been summed to give total annual catchment water yield. This study has used 60 per cent of recharge as a calculated estimate of groundwater flow that discharges to stream (baseflow), the remaining 40 per cent is lost to evapotranspiration and groundwater throughflow. The
60 per cent groundwater flow discharge rate is based on a calibrated BioSim surface water model at the Bright gauge (403205), which is a similar environment (local groundwater flow system) to the state's upland RFA regions.

For catchment water yield valuation purposes, RFA regions were divided into the following catchment zones (see Figure 40):

- Regulated catchments (catchment areas supplying reservoirs)
  - Melbourne Water catchments
  - Irrigation zone supply catchments (supply to trading zones, refer to Figure 41)
  - Other regulated catchments (non-trading zones)
- Unregulated catchments
  - Sustainable diversion limit (SLD) catchments
  - Non-SDL catchments

Contributing areas to reservoirs were either calculated using ArcGIS hydro tools or sourced using SDL, Proclaimed Water Supply Catchment (PWSC) or Australian Hydrological Geospatial Fabric (AHGF) pre-determined catchment boundaries.

Figure 40 Water yield catchment valuation zones

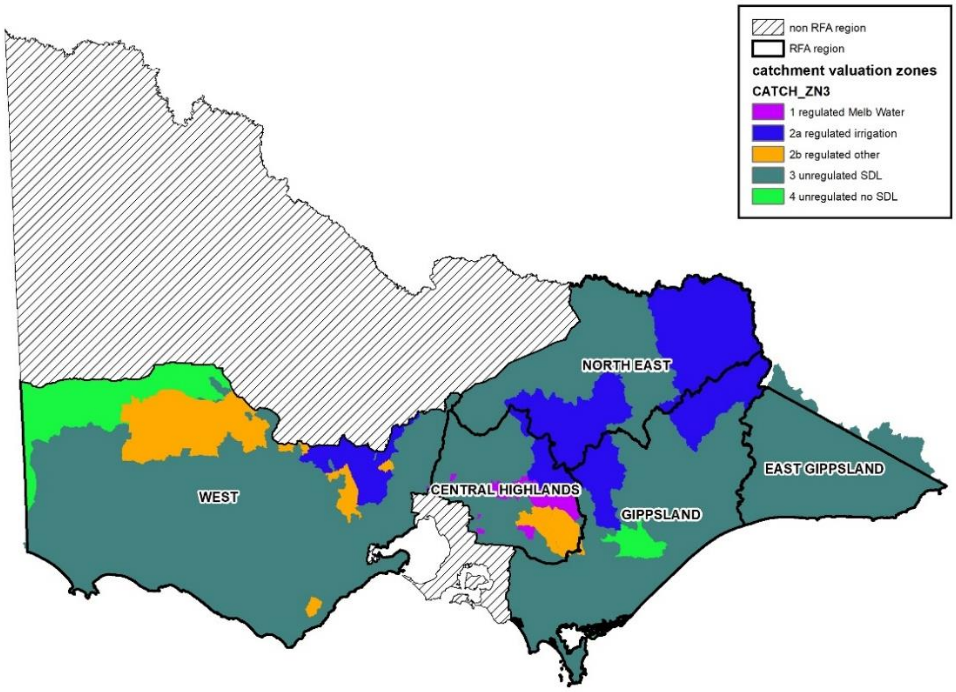


Figure 41 Registered trading zones[160]

Trading Zone	Trading Zone description
1A	**Greater Goulburn** Lake Eildon; Goulburn River from Lake Eildon to Goulburn Weir; Lake Nagambie; Shepparton, Central Goulburn, Rochester and Pyramid-Boort irrigation areas except the Boort irrigation area.
1B	**Boort** Boort irrigation area
1L	**Loddon Weir Pool**
2	**Broken: Nillahcootie to Casey's Weir** Lake Nillahcootie; Broken River from Lake Nillahcootie to top of Casey's Weir pool; Casey's Weir pool; Broken River from Casey's Weir pool to the Goulburn River; Upper Broken Creek from Broken River to Waggarandall Weir, including Major Creek.
3	**Lower Goulburn** Goulburn River downstream of Goulburn Weir.
4A	**Campaspe** Lake Eppalock; Campaspe River from Lake Eppalock to Waranga Western Channel; Campaspe irrigation district.
4B	**Coliban channel system** Coliban channel system.
4C	**Lower Campaspe** Lower Campaspe River, from downstream of the Waranga Western Channel to the River Murray
5A	**Loddon** Tullaroop Reservoir; Tullaroop Creek from Tullaroop Reservoir down to Loddon River; Cairn Curran Reservoir; Loddon River from Cairn Curran Reservoir down to top of Loddon Weir Pool; Serpentine Creek system upstream of Bear's Lagoon.
5B	**Bullarook** Hepburns Lagoon, and downstream to Bullarook Creek; Newlyn Reservoir; Bullarook Creek from Newlyn Reservoir to Creswick Creek.
6	**Vic Murray Dartmouth to Barmah** Lake Hume; River Murray from Lake Hume to Barmah Choke; Lake Dartmouth; Mitta Mitta River below Lake Dartmouth; Murray Valley irrigation area, excluding Lower Broken Creek.
6B	**Lower Broken Creek** Lower Broken Creek downstream of Katamatite.
7	**Vic Murray Barmah to SA** River Murray from Barmah Choke to the South Australian border; Torrumbarry irrigation area; Tresco irrigation district Nyah irrigation district; Robinvale irrigation district; Red Cliffs irrigation district; Merbein irrigation district; First Mildura irrigation district (Note – this now includes the previous trading zone 8)
9A	**Ovens** Lake Buffalo; Buffalo River downstream of Lake Buffalo; Ovens River downstream of the confluence with the Buffalo River.
9B	**King** Lake William Hovell; King River downstream of Lake William Hovell.
9C	**Lower Ovens** Ovens River downstream of the confluence of King River.
10	**NSW Murray above Barmah Choke** River Murray from Lake Hume to Barmah Choke, including Murray Irrigation Ltd areas and Wakool Irrigation District
11	**NSW Murray below Barmah Choke** River Murray from Barmah Choke to SA border (including the Edwards/ Wakool system and the Western Murray Irrigation District).
12	**South Australian Murray** River Murray in SA and Trust districts
13	**Murrumbidgee** Murrumbidgee Irrigation and Colleambally Irrigation areas; Murrumbidgee and Tumut below Burrinjuck and Blowering reservoirs (including Yanko, Colombo and Billabong Creek systems)
14	**Lower Darling** Menindee Lakes and the Darling River downstream of the Menindee Lakes

Biomass for timber

Plantation areas were defined using the 'Plantation' dataset from the CSDL 'VMVEG' feature data class which provides a statewide view of hardwood and softwood plantation areas from across Victoria. From the supplied metadata, this dataset sources information under a cooperative agreement with DELWP, the CFA and the major plantation owners/managers and is refreshed yearly. Not all small plantation estates are included, and these are noted to be added overtime on an ad hoc basis. Thus the Victorian data will underestimate total plantation area. The Victorian plantation dataset was compared to the Commonwealth Government ABARES Australia's Plantations 2016 dataset[161] which produces higher plantation area values than the Victorian dataset. This is due to the above stated reason and, on investigation by comparing aerial imagery in northeast Victoria, it was found that numerous areas stated as plantation in the ABARES dataset were not actually plantation areas. It could also be a factor that the ABARES dataset overestimates plantation area, thus the correct area could be somewhere in the middle of the ABARES and Victorian Government data.

Fodder

Information on agricultural grazing licenses/leases on public land were sourced from the 'PLM25' dataset which is housed within the CSDL. The number of agricultural grazing licenses/leases intersecting with

160. Victorian Water Register

161. Available at http://www.agriculture.gov.au/abares/research-topics/forests/forest-data#australian-plantation-statistics

each tenure type has been calculated using ArcGIS. Only licenses and leases that contain forested areas were included in the assessment. Any non-forest areas of agricultural licenses or leases are excluded. Forested areas were defined using the VFMP forest extent dataset. The following PLM25 tenure classes are classified as 'agricultural' and included in the assessment.[162]

ALPINE CONTIGUOUS GRAZING

ALPINE GRAZING LICENCE

BUSH GRAZING - SEASONAL

CONSERVATION LICENCE - WF

CULTIVATION/GARDEN LICENCE

GRAZING - SOFTWOOD PLANTATION OPS

GRAZING LICENCE

GRAZING LICENCE - NON PRIM PRODUCERS

GRAZING LICENCE (CROPPING APPROVED)

GRAZING LICENCE (W)

INDUSTRIAL/COMMERCIAL LICENCE

MISCELLANEOUS (GENERAL) LICENCE

RECREATION/AMUSEMENT LICENCE

RESERVE (DIR MGT) BUSHLAND

RESERVE SEC 17D (NOT EXTRACTIVE)

RIPARIAN MANAGEMENT LICENCE

UNUSED ROAD LIC. - BLUE GUM PLANTATION

UNUSED ROAD LICENCE - AFFORESTATION

UNUSED ROAD LICENCE - NON PRIM PROD

UNUSED ROAD LICENCE - NON PRODUCTIVE

UNUSED ROAD LICENCE - PRIMARY PROD

WATER FRONTAGE LICENCE - BOX IRON BARK

WATER FRONTAGE LICENCE - NON PROD

WATER FRONTAGE LICENCE - PRIM PROD

WATER FRONTAGE LICENCE - RECREATION

Mining

Information on current mining licences was sourced from the 'MIN' feature dataset which is housed within the CSDL.

The number of mining leases intersecting with each tenure type has been calculated using ArcGIS. Note that one mining licence could intersect with multiple tenures so this isn't a total count of licences rather just a count of intersection between licence areas and tenure types within each RFA assessment area.

162.Available at https://discover.data.vic.gov.au/dataset/public-land-management-plm25

Soil retention (erosion control)

Sediment discharge in mass/time is calculated as a metric for water quality. BioSim was used to calculate gross daily sediment discharge rates per catchment and then an appropriate sediment delivery ratio (SDR) was applied to derive net annual sediment discharge values per catchment which were converted to net sediment discharge in volume/time.

BioSim calculates erosion rates for every solution cell in the modelling domain which, if summed, provide a modelled value of gross sediment catchment yield (t/ha). BioSim does not model sediment attenuation processes such as in stream sediment storage and deposition processes prior to the catchment discharge point, thus a net sediment delivery ratio (SDR) of 0.18[163] has been applied to the gross annual catchment yield. SDR is defined as the ratio of sediment delivered at the catchment outlet (or some other defined location in a catchment) to gross erosion within the catchment, to take account of the sediment storage on route to a catchment outlet. This approach is in line with the hydrological analysis undertaken by Alluvium for the Valuing Victoria's Parks project.[164]

EnSym calculates gross erosion in mass (tonnes) on a daily timestep. To convert from a mass (tonnes) to a volume (m^3), estimates need to be made on the average particle bulk density. The Soil and Landscape Grid of Australia[165] bulk density dataset was used to calculate average bulk density for each RFA region (see Table 48). Bulk density varies spatially based on the mineral composition of different geologies and thus soil types.

Table 48 Mean bulk density values for each RFA region

RFA region	Mean bulk density (gm/cm^3)
Central Highlands	1.084
East Gippsland	1.104
Gippsland	1.128
North East	1.114
West	1.28175

Water flow regulation (flood mitigation)

Water flow regulation services have been modelled with BioSim by comparing water yield under a current land cover scenario to a counterfactual scenario where all trees are removed and 100 per cent of the catchment is modelled as pasture.

For the Wangaratta flood mitigation case study, modelled daily surface runoff and lateral subsurface flow have been summed to give an estimate of peak catchment flow. Recharge has not been included in the peak flow calculation as groundwater flows typically peak later than surface and subsurface lateral runoff

163. Vanoni, V 1975, *Sedimentation engineering practice*, American Society of Civil Engineers, manuals and reports on engineering practice, no. 54, p. 745.

164. Marsden Jacob Associates 2014, *Valuing the water services provided by Victorian parks*, report prepared for Parks Victoria, Annexure C.

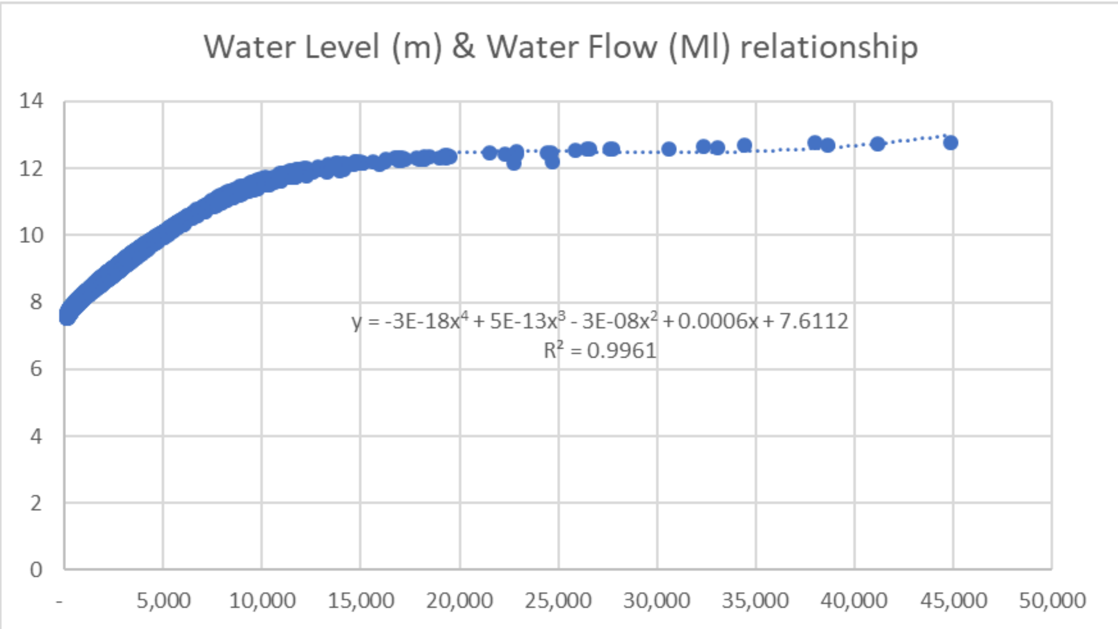
165. Viscarra Rossel, R, Chen, C, Grundy, M, Searle, R, Clifford, D, Odgers, N, Holmes, K, Griffin, T, Liddicoat, C & Kidd, D 2014, Soil and Landscape Grid National Soil Attribute Maps - Bulk Density - Whole Earth (3" resolution), Release 1, Version 5, CSIRO. Available at http://www.clw.csiro.au/aclep/soilandlandscapegrid/index.html

that create peak flood events. This will result in underestimating non-peak flows at the Wangaratta gauge, however will also result in not including groundwater baseflow volumes in the peak flows which would result in overestimating flood heights and flow volumes.

Using BioSim, daily flow volumes in megalitres were modelled for the Ovens River at the Wangaratta gauge (number 403200) for current land use and counterfactual scenario (2008-2018). Daily peak flow volumes were calculated by summing surface runoff and lateral subsurface flows for all contributing model cells upstream of the gauge 403200. Daily flow was retarded by 2 days to reflect the general travel time taken for flood events to arrive at Wangaratta post peak rainfall events. This is obviously a generalisation and such timing would be variable based on the location of the heaviest rainfall. As mentioned previously, BioSim does not model any instream dynamics, thus the incorporation of a river flow model would improve the timing and quantity and peak flow volumes.

The proportional change in modelled flow volumes between the current land cover and the counterfactual scenario with no trees was then applied to recorded stream flow values at the 403200 Wangaratta gauge, which were sourced from the Victorian Water Data Information System166. Daily stage heights in metres were calculated from daily flow volumes using a flow rating curve (refer to Figure 42) for the 403200 Wangaratta gauge. Stage heights for peak flood events then allowed for correlation to flood classes (minor, moderate and major) for valuation purposes.

Figure 42 Rating curve – stage height (vertical axis) and water flow (horizontal axis) relationship for the 403200 Wangaratta gauge



166. Available at http://data.water.vic.gov.au/

To extrapolate the Wangaratta data across the following steps were undertaken:

- From the VLUIS data 'built up areas' were defined using residential, commercial and industrial classified parcels along with areas classified as 'urban void'. Of those any were removed that had agricultural landcover classifications or separate curtilage.
- 'Built up areas' were then intersected with the 1 in 100-year flood and locality polygons, this then created a layer that effectively provided information on all 'built up areas' within the 1 in 100-year flood zone identified with locality name.
- The centroid of each localities 'built area' within the 1 in 100-year flood zone was snapped to the closest major hydrology line. This point was then used to build an upstream contributing area using Atc Hydro tools and a 250 metre digital elevation model resampled to 250 metre.

Carbon sequestration and storage

Above ground biomass data has been used to calculate stock of above ground carbon across Victoria's public land estate. The biomass data was produced through a joint DELWP-RMIT[167] project that integrated 30 years of Landsat satellite imagery with VFMP forest monitoring data.

This dataset only reports biomass on the public estate, thus carbon stocks on any forested private land are not included.

This dataset only reports above ground biomass so excludes below ground biomass stored in living root systems and in within soil carbon. Below ground biomass accounts for approximately 20 per cent of total biomass.[168]

To convert biomass to carbon a factor of 0.47 has been used. This is the value reported by the Australian Greenhouse Office as the mean across 19 eastern Australian native tress species for the percent of carbon content in tree branches.[169]

The biomass data provided by the VFMP contained 26 geotiff raster files in 30 metre resolution. Only 26 of the 30 years of data (1988-2017) were provided – data for 1999-2002 was not available, however is understood to have been produced.[170] The data was resampled to 100 metre resolution in ArcGIS to enable faster processing and then all 26 rasters were imported to EnSym for analysis.

Honey and pollination

Using the Victorian apiary sites dataset from the CSDL the number of apiary sites and average distance from apiary site to forested extent area per RFA regions and tenure class has been calculated. This dataset records licenced apiary sites on public land only, it does not include hive sites located on private land. In some locations the closest mapped forest extent to a licenced public land apiary site is on private land.

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167. Nguyen, T, Jones, S, Soto-Berelov, M, Haywood, A, Hislop, S (2018, in review) 'A comparison of imputation approaches for estimating forest biomass using Landsat time-series and inventory data', *Remote Sensing*, 2018, in review.
168. Ravindranath, N & Ostwald, M 2008, 'Methods for below-ground biomass' in *Carbon inventory methods handbook for greenhouse gas inventory, carbon mitigation and roundwood production projects,* Advances in Global Change Research, volume 29, Springer, Dordrecht.
169. Gifford, RM 2000, *Carbon contents of above-ground tissues of forest and woodland trees*, National Carbon Accounting System technical Report No. 22, Australian Greenhouse Office, Canberra, p. 24.
170. Salahuddin Ahmad pers. comm.

ArcGIS was used to calculate the distance, from each point within Victorian apiary sites dataset, to the nearest polygon of mapped forest extent and was also used to calculate the count of Victorian apiary site points within each tenure class.

Habitat for species

The range weighted species richness data sourced from the Arthur Rylah Institute's Integrated Biodiversity Values Model (IBVM) is a raster dataset at 75 metre grid cell resolution. The value in each cell is a sum of the proportion of species' distribution covered by that grid cell for 35 terrestrial threatened species that are expected to be acutely affected by timber harvesting.

For each RFA region and tenure combination the grid cell values were summed then divided by the area of that RFA region and tenure combination then divided by 35 (being the number of species). This provides a mean value of the proportion of a species' habitat that occurs, per hectare, within each RFA region and tenure combination (for the 35 terrestrial threatened species that are expected to be acutely affected by timber harvesting). To make these numbers more meaningful and easier to interpret they were then multiplied to report the proportion of a species' habitat that occurs per 10,000 km^2 within each RFA region and tenure combination. ArcGIS was used to undertake this analysis.

Note that the IBVM project utilised their own 'woody vegetation' extent mapping. This differs from the forest extent mapping used in other areas of this assessment.

General limitations

Although each of the EnSym modules have undergone extensive testing and calibration and proved their capabilities, BioSim has not been specifically calibrated for this project. The outputs created are useful for catchment scale, relative assessment. For more detailed site-specific data where absolute values are important, calibration and validation should be a priority.

The water yield modelling outputs are made on the assumption that 60 per cent of recharge returns to stream as baseflow. This will be more accurate in the highland areas where groundwater flow systems are short and relatively shallow, however less accurate in lower relief areas where groundwater flow systems are much larger and it would be expected that larger volumes of groundwater would leave the catchment by discharge into other aquifers. Linking EnSym to a groundwater flow model such as Modflow would alleviate this issue, however adds an extra level of complexity and time commitment.