Threatened Species Recovery Hub

National **Environmental Science** Programme

Experimental Ecosystem Accounts for the Central Highlands of Victoria

Summary Report

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Australian National University

FENNER SCHOOL OF ENVIRONMENT AND SOCIETY

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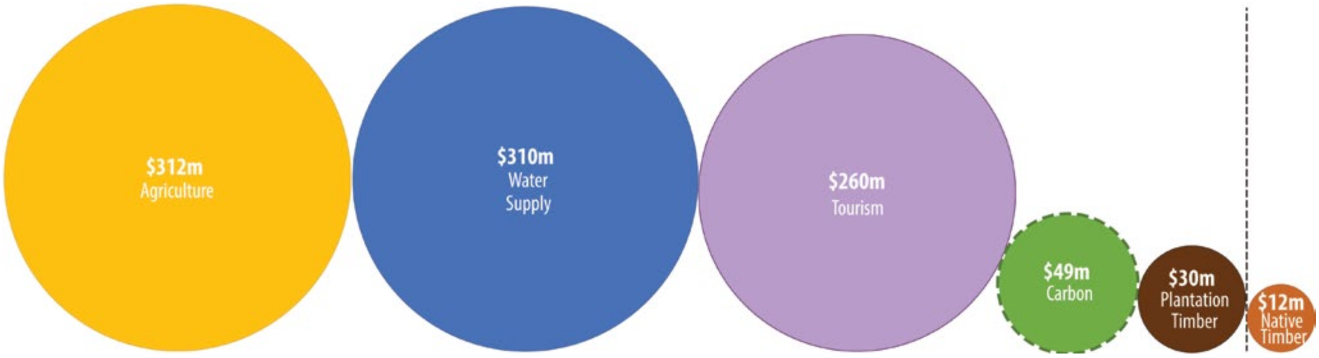
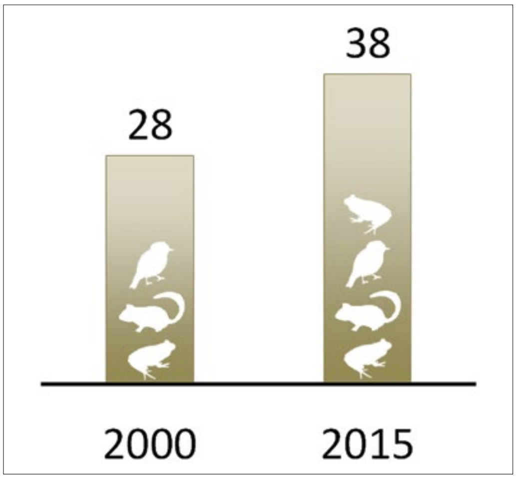
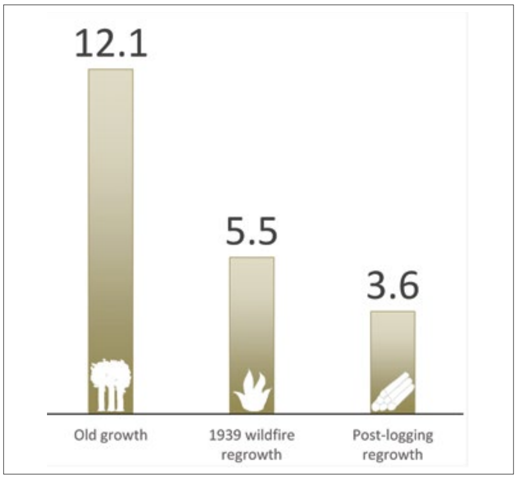
Key Findings



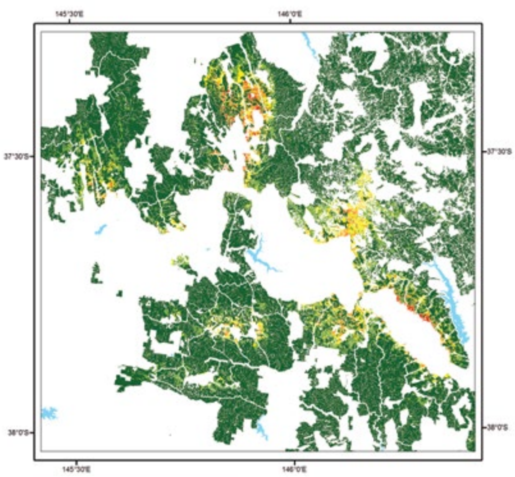
Economic contribution (Industry Value Added) of key regional industries substantially outweighs that of native timber harvesting in Victorian Central Highlands study area. Note: carbon sequestration is estimated as a potential value, as Federal Government regulation currently excludes native forests from the carbon market.



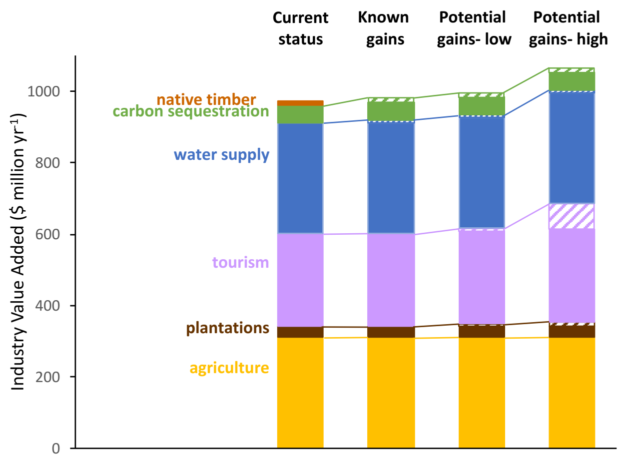
Number of listed threatened species (in Commonwealth EPBC Act) native to the Central Highlands of Victoria has increased by more than a third since 2000.



Number of hollow-bearing trees per hectare (HBTs) is more than three times higher in old growth forest, than in regrowth forest post-logging.



'Hotspot' areas (yellow, orange and red) identify where highest value of ecosystem services for native timber conflicts with maximising services of water provisioning and carbon storage, in the forest areas available for harvesting.



Trade-offs in IVA between key industries highlight substantial potential gains across other industries if native timber harvesting were phased out.

Executive Summary

Policy context for natural resource management in the Central Highlands

- Public controversy arising from conflicting land use activities in the Central Highlands region is long standing. Managing the various land use activities within the region is complex and requires evaluation of trade-offs between different land uses.
- Land use activities include native forest and plantation timber production, agricultural production, water supply, carbon sequestration, recreation, and biodiversity conservation.
- These activities are dependent on ecosystem services, and their use can be either conflicting or complementary. In particular, native timber harvesting is potentially in conflict with other land uses, such as tourism, water supply, carbon sequestration and biodiversity conservation.
- Ecosystem accounting provides a means of quantitatively comparing various land use activities and trade-offs between different activities.
- The Regional Forest Agreement, which is a 20-year plan for allocation of natural resource use within the forests, is due for re-negotiation by 2018.
- Proponents within the native timber industry have called for an expansion of wood supply allocated for native timber harvesting. By contrast, stakeholders within the environmental and tourism sectors have proposed additions to the national park network as the Great Forest Reserve System.

Key findings of the ecosystem accounts for the Central Highlands of Victoria

- The value of ecosystem services used in 2013-14 for agricultural production was $121m and the water provisioning service was $101m, which were an order of magnitude greater than the native timber provisioning service ($19m).
- The contribution to GDP (Industry Value Added value) of the agriculture ($312m), water supply ($310m) and tourism ($260m) industries were all more than twenty times higher than for the native forestry industry ($12m).
- The potential IVA of carbon sequestration was estimated at $49m, based on the recent national carbon price, which is higher than the IVA of native timber production ($12m). Access of native forests to the carbon market is currently excluded by government regulation.
- Ecosystem condition declined over time, with a decrease in areas of older forest. Notably, the total area of older montane ash forest and rainforest reduced by one third over a 25 year period.
- Biodiversity declined over time. This is indicated by the:
  - i. increase in the number of threatened species from 28 in 2000 to 38 in 2015 and the severity of their threat category;
  - ii. decline in the number of arboreal marsupial animals;
  - iii. decline in condition of the habitat consisting of large, old, hollow-bearing trees within a complex forest structure.
- The key threatening process for arboreal marsupials is native forest logging, which results in the accelerated loss of existing hollow-bearing trees and the impaired recruitment of new cohorts of these trees. Areas impacted by logging lose more than half of the retained large trees within a few decades.
- Spatial distributions of ecosystem services across the region identified ‘hotspots’ where provisioning of native timber conflicts with maximising services of water provisioning and carbon storage.
- This final report is a revision of the draft used for discussion in mid-2016. Revisions have been made based on feedback from a workshop in Melbourne, comments from national and international experts, updated spatial data from the Victorian government and other data, as well as additional analyses of the results.

Key findings with implications for management decisions

- The economic benefits from native forest logging are small compared to other industries in the region.
- Loss of IVA in native forestry could be offset by increases from other industries and by entering the carbon market.
- The main product from native forest harvesting is pulp logs; these can be substituted by wood products from plantation forests and recycled paper. Additionally, plantations can provide some substitute sawlog products.
- The impact of altered native forest logging regimes on the profitability of wood product processing cannot be determined from the publicly available information.
- The net value of ecosystem services would increase if native forest logging were phased out, due to improved ecosystem condition in older forests that continued growing.
- Additional, as yet unquantified, benefits would likely occur through increasing the values of cultural and recreational services, the ecosystem services used in agricultural and plantation timber production, and habitat provisioning.

Ecosystem accounting as a tool for decision-makers

- Ecosystem accounts provide information on the ecosystem services and economic value of land use activities in a format that allows for quantitative comparison and analysis of trade-offs. Ecosystem accounting is thus a powerful tool to guide policy-making about regional land management issues.
- Evaluating the contribution of ecosystem assets and services to human well-being is increasingly considered critical to decision-making about natural resource use.
- The ecosystem accounts presented here follow the internationally recognised statistical standard of the System of Environmental-Economic Accounting (SEEA) (UN et al. 2014a, UN et al. 2014b). Goods and services accounted for include those already within the economy, and thus currently assessed within calculations of Gross Domestic Product (GDP) and the System of National Accounts (SNA) (ABS 2016a), as well as those that are hidden or lie outside the SNA but are within the SEEA.
- The accounts prepared:
  - systematically synthesise environmental and economic data for the region;
  - quantify ecosystem assets (extent and condition), and assess the use of these assets by people (ecosystem services and derived products);
  - link economic and other human activity to changes in ecosystem condition, and track this change over time; and
  - highlight the dependencies of economic activity on ecosystems, and the risks to these ecosystems.
- The ecosystem accounts for the Central Highlands demonstrate that the SEEA can be applied in Australia to deliver information for government decision-making.

Approach to developing ecosystem accounts

- Biophysical and economic data from a range of sources were linked spatially and based on classifications of land cover, land use and forest age.
- Accounts using physical metrics were developed for water, land, timber and carbon as well as for the habitat provisioning services for biodiversity.
- Monetary valuations were prepared for the provisioning of water, timber from native forest and plantations, agricultural production of crops, fodder and livestock; cultural and recreational services; and regulating services of carbon sequestration.
- Valuations employed exchange values used in accounting, rather than welfare values (such as willingness to pay) used, for example, in cost benefit analysis.
- Environmental-economic interactions were evaluated at three levels:
  i. values of ecosystem services, those wholly or partly within the SNA, as well as those not currently included in the SNA.
  ii. values of economic uses of ecosystem services by industries as their contribution to industry value added (IVA). The sum of all IVA in an economy equals GDP.
  iii. potential gains and losses in IVA and ecosystem services involved with impacts and trade-offs between land uses.

Actions supported by the findings of the report

1. Land management in the Central Highlands of Victoria.

The ecosystem accounts and analysis presented here suggest that **transitioning away from harvesting of native forests would contribute directly to improved economic, social and environmental benefits** for the people of Victoria:

- Economic
  1. Increasing the value of ecosystem services of provisioning for water, culture and recreation, and carbon sequestration.
  2. Maximising water yield and quality and hence increasing the amount of water available to Melbourne and surrounds.
  3. Re-directing government investment to land use activities with a higher rate of return.
  4. Incentivising private investment in tourism, agriculture and plantation forestry.
- Social
  1. Encouraging increased employment particularly in tourism, and possibly plantation forestry and native forest management for carbon storage and recreation.
  2. Improving quality of the environment for residents and visitors, and services for recreation and aesthetic amenity.
- Environmental
  1. Conserving biodiversity and in particular reducing the main threatening process to Leadbeater's Possum.
  2. Climate change mitigation by maximising carbon stocks in forests.

2. Development and implementation of environmental – economic accounting

- This report supports the goal of governments and the research community to progress work towards **developing a consistent, national framework for environmental accounting** based on the UN System of Environmental-Economic Accounting as important for informing decision-making.

Ecosystem accounting, which spatially links biotic and abiotic components of ecosystems across the landscape, contributes to the broader environmental accounting. The findings presented in the report highlight the advantages of ecosystem accounting as a tool to support decision-making with regard to natural resource management at regional, state-wide and national levels. This analysis thus supports the approach currently underway by federal, state and territory ministers, policy-makers and researchers towards developing a consistent, national framework.

- The findings from this case study highlight the need to develop **options for expanding the range and compatibility of data available** to populate environmental accounts, including design of monitoring systems.

A critical task for future work on ecosystem accounting is to examine the range of data needed for comprehensive accounts, compared with the data available, and its suitability for decision-making.

This report highlights a range of conceptual issues and considerations for data collection and analysis that impact on the feasibility of implementing a national framework for ecosystem accounting. These are **outlined in Section 11 of this report**.

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1. Introduction

1.1 Rationale for ecosystem accounts in the Central Highlands

This report presents the Experimental Ecosystem Accounts for the Central Highlands of Victoria. The primary aims of the report are: (i) to provide information relevant to decision-making about natural resource management in the region, and (ii) to determine the extent to which the System of Environmental-Economic Accounting (SEEA) (UN et al. 2014a,b) can be populated with existing data. This final report is a revision of the draft used for discussion in mid-2016. Revisions have been made based on feedback from a workshop in Melbourne, comments from national and international experts, updated spatial data from the Victorian government and other data, as well as additional analyses of the results.

Current natural resource management in the Central Highlands of Victoria (Figure 1) is contending with conflicts in land use activities. The region contains a range of landscapes including human settlements, agricultural land, forests, and waterways. The boundary of the study area reflects the priority area for land management decisions and availability of key data. Selection of a boundary is complex because many sources of data are integrated in the accounts, and each source has different boundaries. Land use activities include timber production, agricultural production, water supply, carbon sequestration and recreation (Figure 2). These activities are dependent on ecosystem assets and services, and their use can be either complementary or conflicting. The region is also home to a wide range of species, including the endemic and critically endangered Leadbeater's Possum and Helmeted Honeyeater, the two faunal emblems of Victoria. Managing the various activities within the region is complex and requires evaluation of the trade-offs between different land uses. Synthesising environmental and economic information in the form of ecosystem accounts provides a basis for quantitative comparisons in physical and/or monetary terms that can guide decision-making.

The region forms part of the Central Highlands Regional Forest Agreement that is due for re-negotiation within two years. Proponents within the native timber industry have called for an expansion of supply allocated for native timber harvesting. By contrast, stakeholders within the environmental and tourism sectors have promoted an expansion of the national park network proposed as the Great Forest Reserve System. '

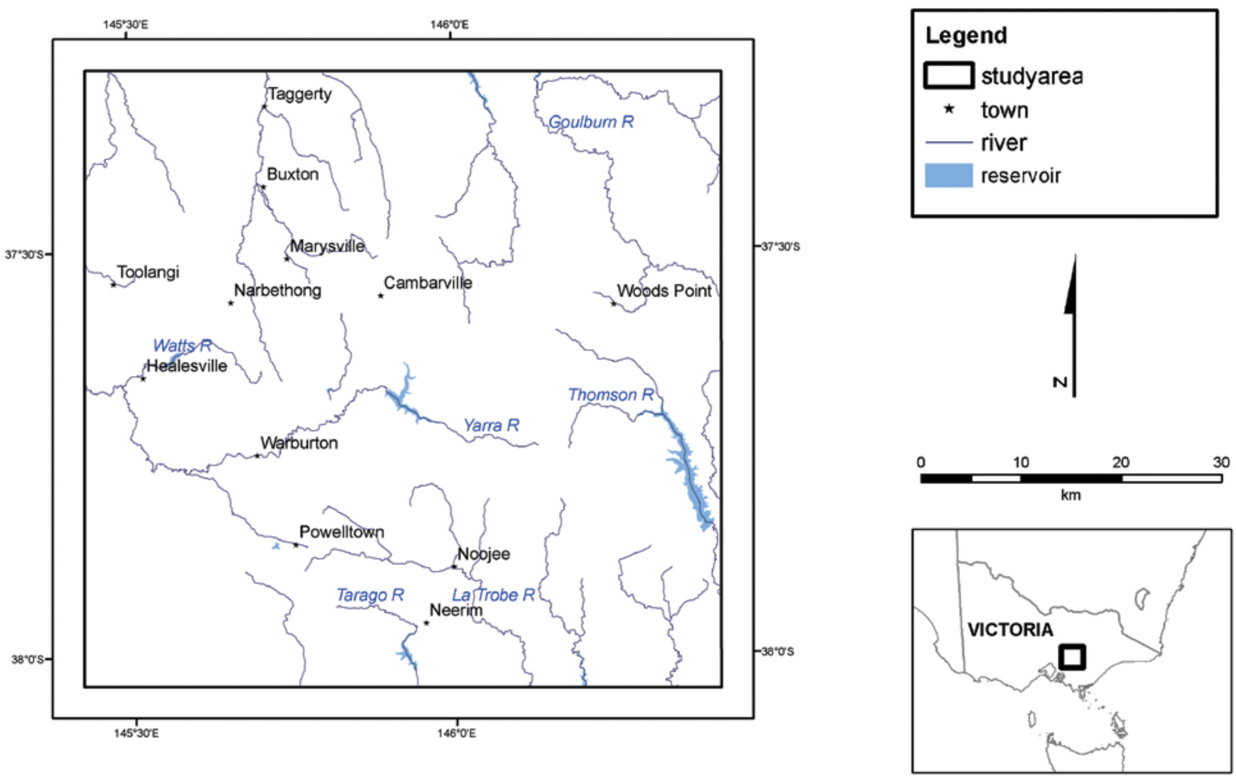


Figure 1. Location of the Central Highlands study area, approximately 100 km northeast of Melbourne.

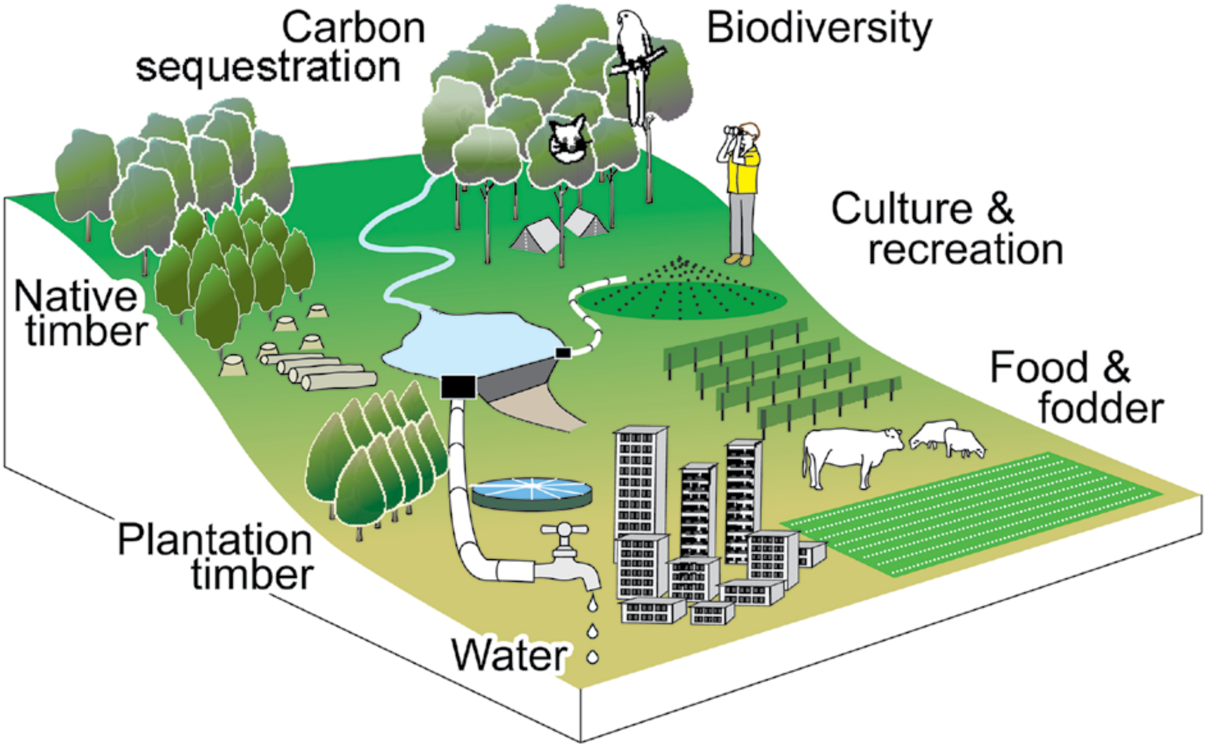


Figure 2. Range of ecosystem services quantified in the Central Highlands landscape.

1.2 Ecosystem accounts informing decision-making

The SEEA (UN et al. 2014a, UN et al. 2014b) was developed by the international community to provide a statistical standard for measuring environmental and ecosystem assets and services. The system complements the economic accounting of the System of National Accounts (SNA) (EC 2009) by adding environmental information. The accounting framework covers component accounts – for example, land, water, carbon, biodiversity – and accounts for ecosystem extent, condition and services. The goal of the SEEA is to demonstrate the benefits that the environment provides to people along with the costs to the environment brought about by human activities, in a form compatible with traditional economic measures, such as GDP (Gross Domestic Product), so that the environment is better included in mainstream decision-making.

Ecosystem accounting describes interactions of living organisms and components of the environment within specific geographical areas. Ecosystem assets and the services provided are located spatially across the landscape. The accounts create a structure for integrating complex biophysical data, tracking changes in the condition and extent of ecosystems, and linking these changes to economic and other human activity, and the benefits they provide to society. The environmental and economic characteristics presented for a region show both ecosystem assets (in terms of extent and condition), together with the flows or uses of these assets by people (in terms of ecosystem services and derived products). Goods and services accounted include those within economic systems, and hence calculations of GDP and within the SNA (ABS 2016a), as well as those that lie outside these systems as unrecognised contributions of ecosystems to economic activity and human well-being (UN et al. 2014b).

A model of ecosystem accounting (Figure 3) shows the connection between ecosystem assets or stocks, the flows of ecosystem services, and their relationship to traditional economic measurement in the SNA. Components of the system can be quantified with metrics in physical or monetary terms. Only parts of the system (indicated by the dashed line in Figure 3) are included in the calculation of GDP, which accounts for flows of market goods and services, such as agricultural products, timber products, water supply, tourism and recreational services. Non-market goods and services not accounted for in GDP include clean air, water filtration, protection from flooding and soil erosion, biodiversity, aesthetic benefits and climate change mitigation. The boundary between market and non-market contributions from ecosystem services (the position of the dashed line in Figure 3) is difficult to define in many cases.

To support decision-making, activities can be assessed at balance points where components of the system are reasonably comparable: the complementary or conflicting use of ecosystem services; trade-offs resulting from the relative impacts or benefits of producing goods and services; and trade-offs between the flows to different beneficiaries within society.

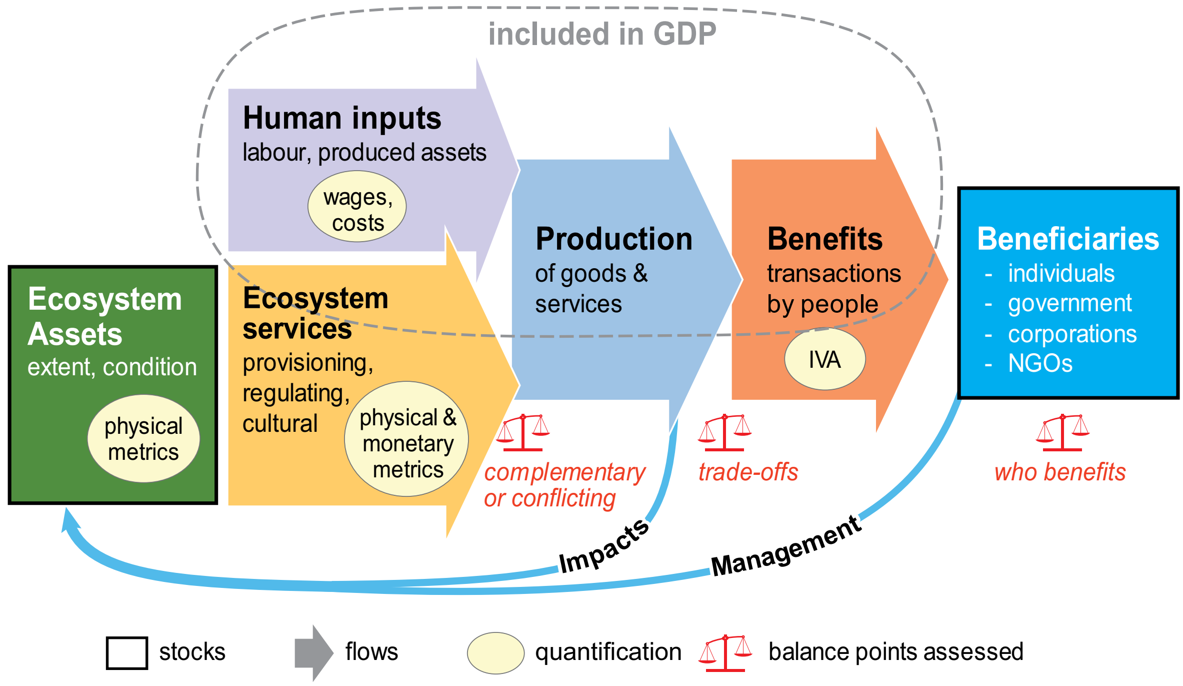


Figure 3. The environmental-economic system showing the stocks and flows of natural resources.

1.3 Outcomes from accounts

Structuring information in the form of accounts reveals the interactions between human activities and ecosystem assets, which may have positive or negative impacts on ecosystem extent and condition. We evaluated natural resource management issues within the region at three levels of the environmental-economic interaction:

1. values of ecosystem services, both currently valued but hidden in other information, and previously unrecognised;
2. values of economic output of industries that use ecosystem services as their contribution to industry value added (IVA) (with the sum of all IVA equal to GDP for the entire economy); and
3. potential gains and losses in IVA and ecosystem services involved with impacts on assets and trade-offs between land uses.

The key outcome was the capacity to quantify ecosystem services and their contribution to industries, and hence explicitly reveal the trade-offs made or required when use of services by different industries conflicted or resulted in a reduction in ecosystem extent or condition.

For the Central Highlands, ecosystem accounts can inform decision-making by:

1. identifying drivers of change in ecosystem extent and condition, including the changing balance of economic activities in the region, biodiversity loss, carbon emissions and reduction in carbon stocks, influence of climate change and variability on water supply, expansion of built-up land and infrastructure and fragmentation of habitats;
2. tracking progress towards policy targets, such as improving regional economic outlook or decreasing risks to threatened species and ecosystems;
3. assessing the sustainable use of natural resources, especially timber and water;
4. assessing the cost-effectiveness of expenditure on conservation of species or habitats;
5. enabling analysis of trade-offs between different land uses and scenario modelling.

The purpose of this report is to produce information that can inform these issues.

Evaluating ecosystem assets and services for their contribution to human well-being is now considered a critical component for improving the decision-making process for natural resource management. This process is relevant at many levels, for example, regional land use conflicts, national conservation policies, State of the Environment reporting, and international agreements such as the Sustainable Development Goals that aim to achieve sustainable development by 2030 (UNDP 2015).

The following sections in this summary report provide an outline of the methods underpinning ecosystem accounts (Section 2) and an analysis of the various land uses in this study area (Section 3).

Ecosystem accounts are presented for each of the key natural resources within the study area in Sections 4-9: water (§4), carbon (§5), timber (§6), agriculture (§7), tourism (§8) and biodiversity (§9). A final synthesis of all accounts and analysis of trade-offs between ecosystem services in the study area are provided in Section 10.

A range of key conceptual and data issues in application of the UN SEEA have been identified in developing this case study, that need to be considered in the further development of coordinated approaches to environmental-economic analysis. These issues are outlined along with concluding remarks in Section 11.

The accompanying full report gives a comprehensive description of the full set of ecosystem accounts for the Central Highlands of Victoria, along with details of data sources, methods and assumptions used in developing these accounts.

Mountain Ash forest. Image: Heather Keith

2. Accounting methods

2.1 Data sources and classifications

The accounts presented for the Central Highlands follow the concepts and terminology of the SEEA (UN et al. 2014a,b). Accounts have been prepared for ecosystem extent and condition (based on land cover, land use and disturbance history), water assets and supply, carbon stocks and sequestration, native and plantation timber assets and supply; as well as information in an accounting format for biodiversity, agricultural production and tourism.

Biophysical and economic data from diverse sources and scales were integrated spatially based on land cover, land use and forest age classifications. Biophysical data tends to be small-scale data with clear spatial references, whereas the available economic data are generally aggregated to industries (agriculture, forestry, mining, manufacturing, education, etc.) and sectors (households, corporations, government, not-for-profit institutions) for large administrative or statistical areas. Spatially linking these data generally means using models and assumptions to scale-up biophysical data and to disaggregate economic data to lower level areas.

The spatial boundary used to define the study area was selected to encompass the areas of contention for timber harvesting or inclusion in a national park network, and the available site-based data. None of the range of existing management areas used for different purposes adequately included the area of interest.

Data sources were derived from publically available information (from websites, already published accounts, annual reports, published literature, etc.), and these data were adapted to fit the SEEA accounting structures and the study area. A critical task for future work on ecosystem accounting is to examine the range of data needed for comprehensive accounts, compared with the data available, and its suitability for decision-making.

In economics, environmental science and accounting, the units of observation, their aggregation and classification are key issues. In national accounting, the units of observation are economic agents classified as sectors (for example, public or private sector), or classified by type of productive activity by industry (for example, agriculture, mining, manufacturing, services, etc.). All economic units can produce (and use) goods and services traded in the economy as well as extract natural resources and return residuals (as pollution or waste) to the environment. Economic units are not spatially bound, although the assets that they own or use and the activities that they undertake can be spatially located in most cases. In ecosystem accounting, the units of observation are particular areas and hence are spatial units. The ecosystem functional units are derived from classifications of land cover, land use and forest age.

The classifications used in these accounts for agriculture, forestry and water supply industries are defined according to the Australia New Zealand Standard Industry Classification (ANZSIC 2016) (ABS and SNZ 2006), which is used by the Australian Bureau of Statistics (ABS) for the production of the national accounts and the environmental-economic accounts. The ANZSIC classification is used to classify businesses to industries based on the predominant productive activity; it is comprehensive (i.e. covers all economic activity) and mutually exclusive (i.e. there is no overlap of categories). Primary production activities of agriculture, forestry and water supply are classified in separate Divisions. Of particular note is the manufacture of wood and paper products is in manufacturing industry not forestry industry. Tourism is not defined in ANZSIC but in a satellite accounting framework of the SNA (ABS 2016d). The Common International Classification of Ecosystem Services (CICES 2016) was used in the accounts at the highest level of classification: provisioning, regulating and cultural services.

2.2 Valuation

Valuation was assessed at two stages in the accounts: (i) the benefits in terms of the economic activity of supply of goods and services, and (ii) the contributions of ecosystems services to those benefits.

A standard metric used to quantify economic activity is Industry Value Added (IVA), which is part of the SNA. IVA is calculated as the revenue from sales less costs, or the gross operating surplus plus wages. Total value of production is the price times the quantity sold, where the price usually represents the production cost plus a profit to the producer. IVA represents the contribution of each industry to GDP – that is, the sum of IVA equals GDP. IVA is applied only to goods and services that are traded within the economy, or could have been traded in the economy, and for which there is a current market (EC et al. 2009). For the Central Highlands accounts, timber, water, agricultural commodities, and the goods and services associated with tourism, which are exchanged within the economy, are valued at the price of exchange. An IVA was estimated for carbon sequestration based on a market price equivalent, using the price of carbon abatement from government auctions less the costs of managing the forest.

The contributions of ecosystem services to the goods and services supplied within the economy - that is, the benefits - are only partly included in the SNA. The aim of ecosystem accounting is to quantify ecosystem services, in physical and/or monetary terms, and include them in the accounts. Valuation methods applied to ecosystem services in the Central Highlands included:

1. unit resource rent for the regulating services used for agricultural and plantation timber production, and cultural and recreational services;
2. stumpage for provisioning of native timber (that is, the sale price less harvest and haulage costs);
3. replacement cost for provisioning of water; and
4. market-based payment system for the regulating services of carbon sequestration.

No economic valuation has been attempted for biodiversity. However, the ecosystem services contributing to habitat provisioning for biodiversity were assessed using physical metrics.

Tree ferns in Mountain Ash forest. Image: Heather Keith

3. Land

3.1 Land cover and use

The land accounts consist of a matrix of land cover and land use, with additional information about land tenure, management and disturbance. The land cover classes gave the structure for the accounting, showing the extent of ecosystem types, and the changing areas of these ecosystems over time. Land use is based on cadastral data showing areas of ownership and use by industry. Land cover provides a link to the production of ecosystem services. Land use and land tenure provide links to the use of ecosystem services, the benefits and beneficiaries. Integrating these spatial data about land cover extent means that ecosystem characteristics can be linked to industries. Table 1 shows the areas within the Central Highlands aggregated by land cover and land use classes.

Table 1. Area of land in aggregated land cover by land use classes within the study area
Areas rounded to the nearest 100 ha to reflect the uncertainty in the intersection of the spatial data.

2015 Area (ha)	Land cover						
Land Use	built/ bare	open water	crops/ pasture/ horticulture	plantation forest	native open vegetation	native forest	Total
urban	29,800		4,300	3,700	2,800	16,000	56,600
agriculture	0		53,700	20,600	1,500	19,900	95,800
plantation forestry	0		0	12,000	0	0	12,000
native forestry	300		0	0	3,300	260,600	264,200
conservation	12,300		0	0	21,600	275,300	298,200
water storage	300	4,400	0	0	400	3,900	8,900
Total	31,600	4,400	5,800	36,300	29,600	575,700	735,700

3.2 Forest age

The condition of native forest was related to forest age, because age is a determinant of the ecosystem services related to water, carbon, timber, aesthetics and biodiversity. Forest age was determined for the area of forested land cover, calculated from the time since disturbance events that resulted in stand replacement. These events included wildfire (high severity fire when information was available) or clearfell logging for montane ash (*Eucalyptus regnans* Mountain Ash, E. *delegatensis* Alpine Ash, E. *nitens* Shining Gum) and rainforest; and clearfell logging for wet mixed, open mixed, woodland and montane woodland.

Change in forest age over time is illustrated by the proportion of the total forest area in each forest age category, showing the result for each 5-year period from 1990 to 2015 (Figure 4). More than half the area is shown as forest older than 75 years. Much of this consists of wet mixed and open mixed forests because the analysis assumes that these are not killed by fire. The proportion of area in the two oldest age categories (before 1939 and 1939-1959), which are forests in the best condition for the provisioning of water, timber, carbon and habitat for hollow-dependant animals, has declined in each 5-year interval, and the area in the youngest two age categories has increased. This was particularly apparent in Mountain Ash forests aged 56-75 years old (the 1939-59 age class) that were reduced from 115,233 ha in 1990 to 79,753 ha in 2015, a 31 per cent reduction in area over 25 years. Thus, the ecosystem condition, as described by forest age, has declined over the last 25 years.

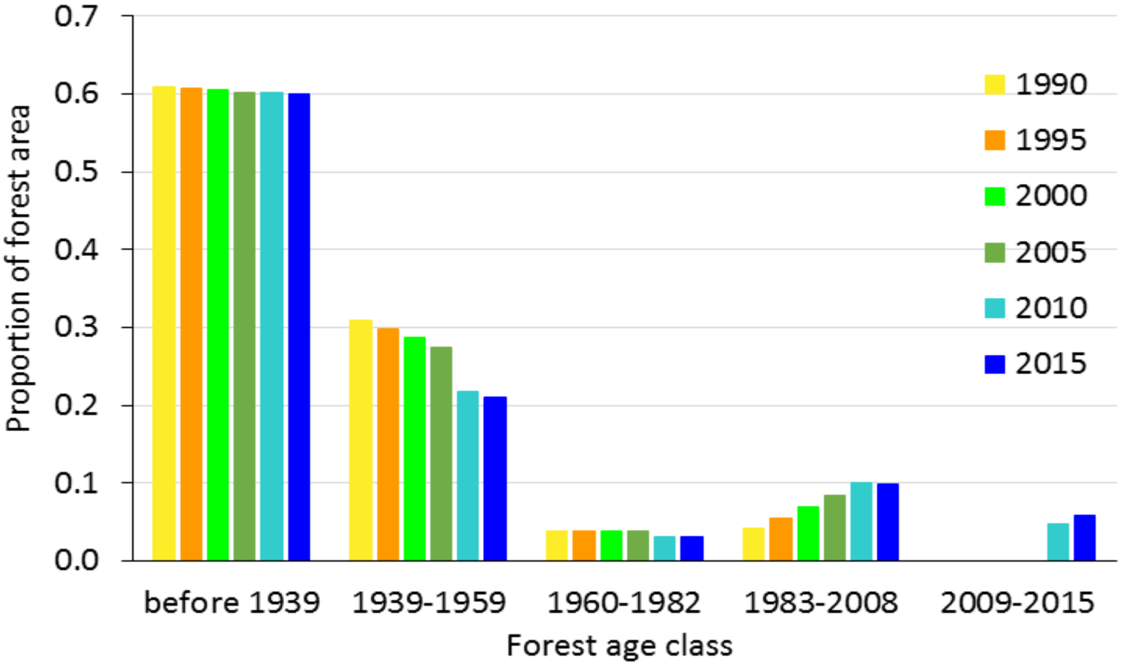


Figure 4. Proportion of total forest area in each forest age category from 1990 to 2015.

The area of montane ash forest within the study area that has no recorded history of disturbance by fire or logging is 216 ha or 0.11% of the total extent of montane ash. This area is considered old growth forest because there are no records of stand-replacing disturbance events. However, spatial analysis of these small areas is highly uncertain and the forest would need to be assessed on the ground to check characteristics of structure and composition that comply with the old growth state.

Mosaic of forest age classes across the landscape. Image: Dave Blair

4. Water

The study region in the Central Highlands contains the majority of the catchment areas for the ten water storage reservoirs of Melbourne Water that supply water to Melbourne and surrounding regions. The water accounts for the period 1990 – 2015 consist of the amount of water stored in the reservoirs, the ecosystem service of water provisioning, and the supply of water to businesses and households. The main sources of data included biophysical data for the study area, Melbourne Water corporation storage and supply data, and financial statements.

4.1 Water account

The water accounts show the annual average water volume stored in reservoirs (stocks), which results from runoff of water from the catchment areas (inflows) derived from a monthly water balance model including precipitation, evaporation, and soil water storage; and abstractions (outflows) of water for supply to consumers, releases for environmental flows and irrigation (Figure 5). The inflows to the reservoirs represent the ecosystem service of water provisioning, while the abstraction and supply of water to businesses and households represent the economic production and benefits. Water demand is influenced by human population size and efficiency of water use.

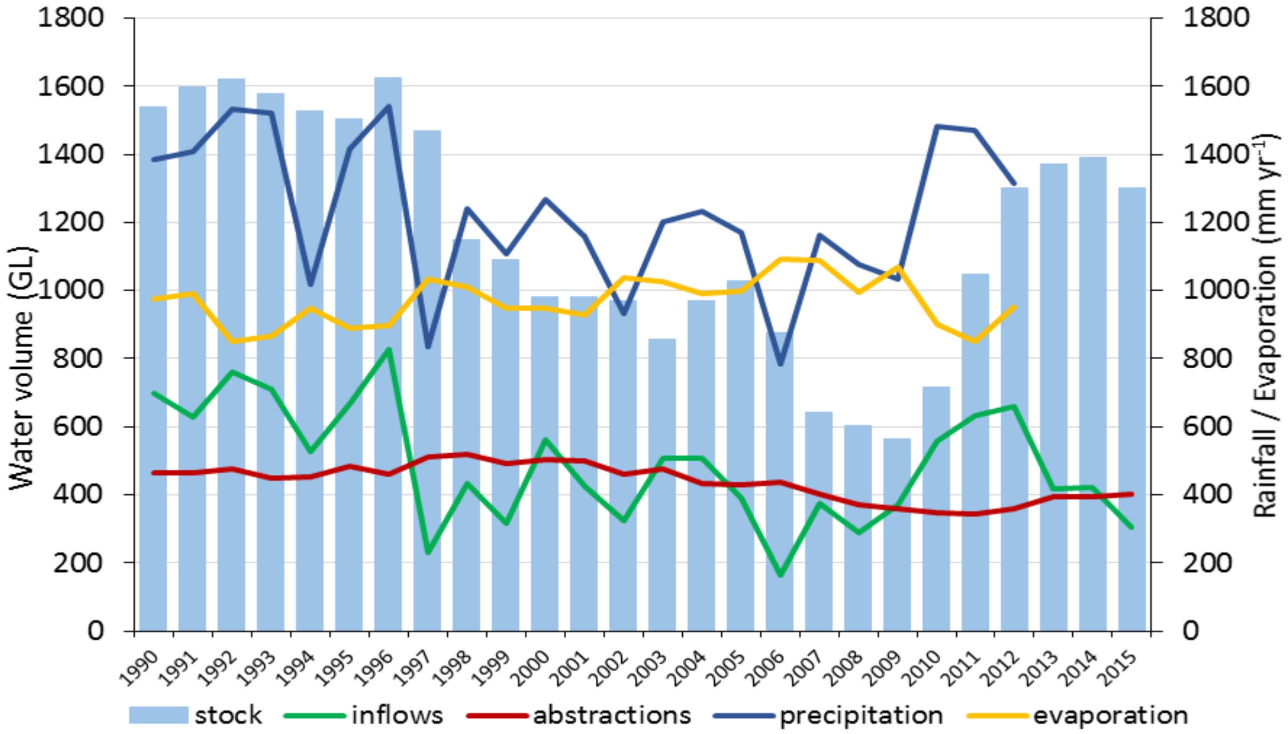


Figure 5. Time series data on precipitation, evaporation, water storage (stock), inflow (runoff), and supply (abstraction) for the Melbourne Water reservoirs and catchments.

[Data source: Melbourne Water (2000-15) and eMAST (2016)]

4.2 Ecosystem service of water provisioning

The ecosystem service of water provisioning was equated to the inflow to the reservoirs used by Melbourne Water. Inflow from runoff was calculated using a spatially explicit water balance model, based on monthly climate data and calibrated with gauged streamflow data (Stein et al. 2009). In addition, the water entering the reservoirs also includes use of the ecosystem service of water filtration.

Changes in runoff over time occur in response to climate variability, land cover change, and disturbance history. Runoff is influenced by the condition of the vegetation, and particularly age in the montane ash forest type (species that regenerate from seed and produce dense, even-aged canopies). The response of runoff to forest age was calculated from a model derived from multiple catchment-scale empirical data (Kuczera 1987). Runoff increases for the first few years after disturbance and then decreases to a reduced proportion of the pre-disturbance forest condition, due to high evapotranspiration demand. The model predicts greatest reduction in runoff between ages of 13-49 years, with maximum reductions of 48 per cent from an old growth forest and 29 per cent from a regrowth forest. Runoff is not fully restored for at least 80 years if a forest is regrowth at the time it is disturbed, or 200 years if a forest is old growth at the time it is disturbed. The spatial distribution of runoff across the landscape shows reduced runoff in areas that have been disturbed by clearfell logging or high severity wildfire, thus producing younger forest ages (Figure 6). The dark blue colour shows the areas of higher runoff, which are generally associated with unlogged areas. The mosaic of individual light blue grid cells within patches of dark blue indicate areas of young regrowth forest after clearfelling, which have reduced runoff.

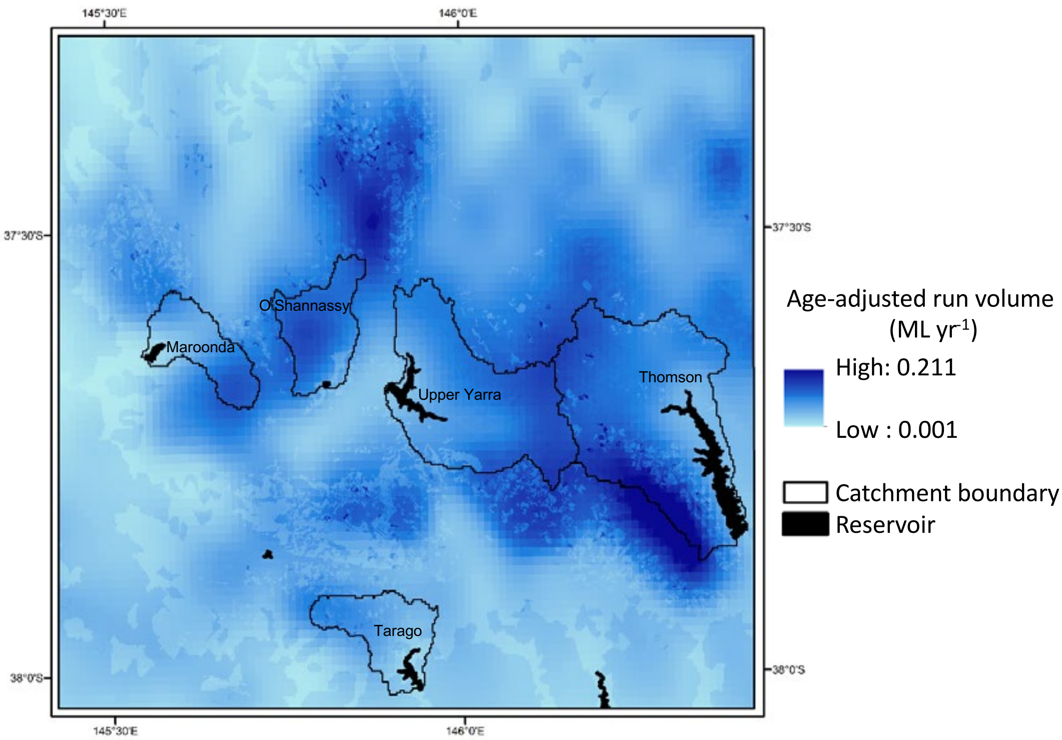


Figure 6. Spatial distribution of modelled runoff in 2012 calculated with changing forest age due to regeneration from wildfire and logging.

4.3 Valuation of water provisioning and water supply

Water supplied into the economy is the result of a combination of fixed capital (reservoir walls, water mains, pumps, etc.), labour, energy and other inputs, as well as ecosystem services. The revenue received by Melbourne Water from water supply activities partly reflects these costs, but additionally, the price of water is regulated by the Essential Services Commission. Hence, the value of sales is not a true market value. The IVA for water supply by Melbourne Water was calculated as the profit (revenue less expenses) plus wages. The water provisioning service was valued using the replacement cost method. That is, if the water were not available from the catchments, the next cheapest alternative source of water would be transfer of water from other regions. However, in practice, a different and more expensive alternative water source from desalination was chosen by the Victorian Government, so the value derived was a lower bound. **The contribution of water supply to Industry Value Added was $310m for 2013-14, and the value of ecosystem services was calculated at $101m.**

The volume of water supplied has decreased between 2000 and 2015 (Figure 5), while the revenue received has increased by 500 per cent since 2008. A step increase in revenue from 2013 to 2014 was associated with a water price rise to cover the cost of the new Wonthaggi Desalination Plant.

4.4 Trade-offs in water provisioning

The water supply catchments cover an area of 115,149 ha within the study area, but only some of this area is protected for water supply. The Upper Yarra, Maroondah and O'Shannassy catchments are protected and only small areas have been, and are available for, logging. The Thomson catchment has 53 per cent of the area protected, and the Tarago catchment 43 per cent protected.

The effects of fire and logging on water yield were disaggregated to analyse the counterfactual case; that is, the case where logging had not occurred in the catchments. The reduction in water yield that has occurred due to logging is approximately 10 GL yr^{-1} since 2010, with the amount increasing each year as the cumulative area of young regenerating forest post-logging increases. **This amounts to a loss of $2.5 million per year to the Industry Value Added of water supply.** Harvesting ash forest on an approximately 80-year cycle means that most of the age classes of the regrowth forest across the landscape have high water demand, and thus reduce water yield. The logging that occurs in the catchment areas supplies about a quarter of the log volumes from the study area.

Acheron River. Image: Dave Blair

5. Carbon

The Central Highlands region contains wet temperate, evergreen forests that are some of the most biomass carbon-dense in the world (Keith et al. 2009). Maintaining ecosystem carbon stocks, by reducing carbon losses from degradation and deforestation, is a critical component of climate change mitigation (UNFCCC 2015).

5.1 Asset account

Spatial distribution of biomass carbon stocks (above- and below-ground, living and dead components) was derived from biomass density modelled in relation to environmental conditions, forest type and disturbance history, and calibrated with site data (Figure 7). Change in carbon stocks was calculated in relation to forest age, based on the disturbance history of logging and fire. Annual increments in carbon stocks were calculated from forest type-specific growth functions. Losses of carbon were calculated due to logging, fire events and decomposition. Constant average carbon stock densities were applied to non-forest land cover types. The total carbon stock within the study area in 2015 was estimated to be 146 Mt C.

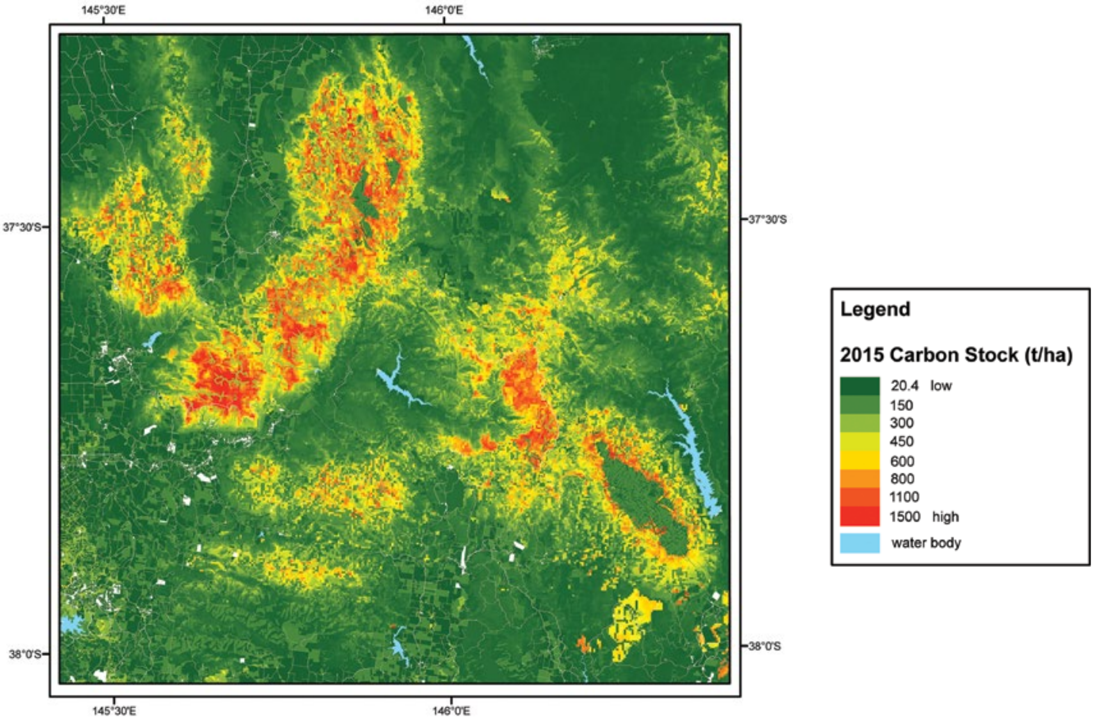


Figure 7. Spatial distribution of the carbon stock density across the study area.

5.2 Ecosystem service account and valuation

The ecosystem service of carbon sequestration was calculated as the net annual change in carbon stock, where positive changes represent removal from the atmosphere and storage in terrestrial ecosystems, and thus have a benefit for climate change mitigation. Sequestration was 1.64 Mt C yr^{-1} in 2015. Based on the national carbon price for abatement of $12.25 per tCO_{2_e} (second auction of the Emissions Reduction Fund in 2015), annual sequestration from all land cover types within the study area had a value of $63 million yr^{-1} (averaged over 2010-2015). While acknowledging that the price of carbon was not the same for earlier years, the 2015 price was applied to earlier years adjusted for inflation using the ABS Consumer Price Index in order to illustrate a more consistent trend and eliminate artificial price distortions across this historically variable context.

The ecosystem service of carbon sequestration has a benefit for climate change mitigation both nationally and internationally. Whether this benefit is recognised in the market depends on government regulations. Under current Australian Government regulations for carbon credits, avoiding harvest and protecting native forests to store carbon is not included under approved methodologies for abatement activities. Hence, calculation of the economic activity of carbon sequestration as an IVA metric represents a potential value if regulations permitted a market transaction. Calculation of IVA was based on the revenue, assumed to be the product of the amount of carbon sequestered and the current carbon price, less the expenses incurred for managing the native forest, assumed to be similar to those for managing a national park.

5.3 Trade-offs in carbon stocks and sequestration

The effect of land use on carbon stocks was considered as two components: (i) the difference between land use types in their carbon stocks, and (ii) carbon sequestration as a net change in carbon stock per year. The carbon stock and rate of net change differ among land cover types, land use activities, and disturbance events.

The difference in carbon stock density of montane ash forest between areas unlogged and logged in 2015 was an average of 143 tC ha^{-1}. This is the carbon stock loss due to logging, but alternatively, represents the carbon sequestration potential if logged forests were allowed to continue regrowing without repeated logging. At a carbon price of $12.25 per tCO_{2_e}, this stock difference is equivalent to $6413 ha^{-1}. Over the area of montane ash forest that has been logged since records began in 1932, this difference in carbon stock is 8.76 Mt C, which is equivalent to $393 million. This represents the difference in value of the current forests managed for harvesting or conservation. In comparison with the gross carbon stock loss from logging of -14.2 Mt C, the stock loss from fires over this period was -3.4 Mt C, with -2.4 Mt C from the 2009 fire. Carbon stock lost during the 2009 fire was re-gained by sequestration within the area burnt over the subsequent five years of regeneration.

The difference in net change in carbon stock density over the study area between the area logged and the area unlogged but available for logging was 2.98 tC ha^{-1} yr^{-1} averaged over 1990-2015. The carbon sequestration potential by ceasing logging is equivalent to $134 ha^{-1} yr^{-1}. Logged forest has a net reduction in carbon stock (gain from growth minus loss from logging due to combustion and decomposition of waste and product removal) of -0.033 Mt C yr^{-1} over the 25-year accounting period, valued at -$1.5m per year. In comparison, net gain in carbon stock, or sequestration, in the unlogged area was 0.43 Mt C yr^{-1}, valued at $19.3m per year over the accounting period.

The price of carbon sequestration in the market does not equate to the social cost of carbon, that is, the marginal damage costs caused by carbon dioxide emissions if they were not avoided. This social cost represents the trade-off between avoided impacts of climate change and the costs of emission reduction. These marginal damage costs have not been included in this study.

Measurement of trees for estimation of carbon stocks. Image: Dave Blair

6. Timber

6.1 Timber volumes harvested

The Central Highlands is an important region in Victoria for the supply of timber and fibre from native hardwood ash and mixed species forests in State Forests, and plantation hardwood and softwood from private land. There has been a long history of native forest logging in the Central Highlands, beginning in the 19th century with selective logging, and increasingly intensified in the 20th century. Most logging is now by clearfelling and slash-burning. Most of the old growth montane ash forests in State Forests, within areas managed for harvesting, that were not burnt in 1939 had been logged by about 1990. Logging of the 1939 regrowth commenced in the mid-1980s and is currently continuing. Most of the timber volume harvested from native forests is used in the Maryvale Pulp Mill, which lies outside of the study region.

Data were collated for the area, volume and yield of sawlogs and residual logs harvested from 1990 to 2014, based on Victorian government department reports and spatial data, ABARES (2016), the plantation company HVP (2016), and the carbon accounting model (DotE 2015a). Spatial data showed larger areas harvested each year than the reported data. As an example of the data, annual wood volumes harvested from native forests and plantations are shown in Figure 8. More than half the wood volume is used as pulp logs. The highest volume of native timber harvested was after the 2009 fire as salvage logging (Figure 8). Areas planted and volumes harvested of both hardwood plantations and softwood plantations have increased, particularly over the last 5 years, with hardwoods used for pulp logs.

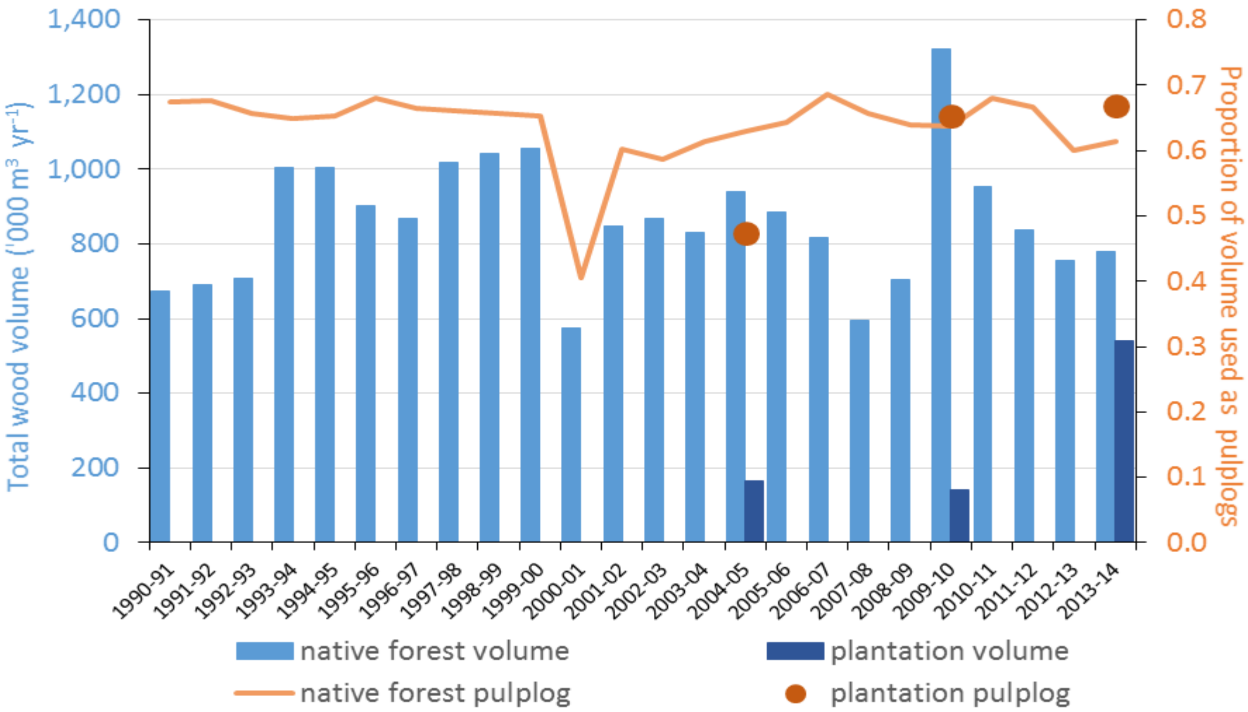


Figure 8. Annual volume of wood harvested from ash and mixed species native forest types, and hardwood and softwood plantations within the study area, and the proportion used as pulp logs.

[Source: DSE (2003-09), VicForests (2007-15), ABARES (2016), DotE 2015a, HVP (2016)]

6.2 Valuation of timber provisioning

The ecosystem service of provisioning of timber for supply to market by VicForests for native forest timber and plantation companies for hardwoods and softwoods was equated with the volume of timber harvested each year. The value of the ecosystem service was based on the reported stumpage value, which is the revenue from log sales less harvesting and haulage costs, and scaled for the volume harvested within the study area. The value of timber production (total revenue from sales) from the Central Highlands and IVA were calculated based on annual reports by VicForests, ABARES and ABS, again scaled to the volume harvested from the study area. IVA was calculated for the industry classification of the primary production activity of forestry and logging in native forests and plantations; this does not include primary or secondary processing. Values for timber from native forests and plantations are compared for the year 2013-14 (Table 2), and the annual pattern is shown in Figure 11.

Table 2.Volume and value of timber from native forests and plantations in the Central Highlands study area in 2013-14

	Native forest	Plantations
Area available for production (ha)	264,154	36,316
Volume supplied (m^3 yr^{-1})	724,300	539,700
Ecosystem provisioning service ($m)	19	9
Ecosystem provisioning service ($ ha^{-1})	71	250
Revenue from timber sales ($m)	49	64
Industry Value Added ($m)	12	30
Industry Value Added ($$ha^{-1}$)	46	823

In the wood production industry in Victoria, 81 per cent of the volume and value are derived from plantations and 19 per cent from native forests. **On a state basis, the softwood and hardwood plantation forestry industry (growing, harvesting and haulage) employs more than twice as many people as the native forestry industry. Within the area of this study, 43 per cent of the wood volume is derived from plantations, amounting to 57 per cent of the value. Employment is approximately 56 jobs in plantations and 150-200 jobs in native forests.**

The Maryvale Pulp Mill uses pulp logs from native timber harvested from the Central Highlands. Alternatives to wood products from native timber exist in the form of recycled paper and plantation timber, so a reduction in native timber supply from the Central Highlands does not mean that this economic activity would cease.

Native forest harvested timber products. Image: Dave Blair

7. Agriculture

Agricultural production relies on a range of ecosystem services, including pollination, abstraction of soil water, soil nutrient uptake, and nitrogen fixation. Some of these services would have been generated on the land used for agricultural production, such as soil water and nutrient uptake, whereas other services may have been generated elsewhere, such as pollination. For this account, all ecosystem services produced and used were allocated to the agricultural land cover.

Agricultural production and costs were obtained for ABS statistical areas, which were mapped against the study area. The resource rent approach was used for calculating the combined value of the regulation and maintenance ecosystem services used in agricultural production. The revenue from agricultural production in the study area in 2013-14 was $659 million, and the ecosystem services used by agriculture were $121 million. **The industry value added was $312 million.**

Range of agricultural land uses. Image: David Blair

8. Tourism

The Central Highlands region is used for a variety recreational purposes that are classed as cultural and recreational services in ecosystem accounting terms. The region includes national parks and other reserves as well as wineries and other tourist attractions. The use of these ecosystem services by people can be assessed as part of the value of the consumption by tourists in the area. This consumption relies not just on the ecosystem services but also capital, labour and other inputs from the industries supporting tourists, for example, accommodation and restaurants.

Tourism Victoria produces accounts including details of total outputs, industry value added and employment within regions based on statistical areas. Data from these accounts were used based on the weighted average for the area of the regions that occur within the study area. The cultural and recreational ecosystem services were estimated using the resource rent approach, which has been used for Tourism Satellite Accounts by the ABS (ABS 2016d, TRA 2015). **The contribution of tourism to industry value added was $260 m in 2013-14 and accounted for 3,500 jobs. The value of the ecosystem service of culture and recreational services was $49 m.**

Recreational activities. Image: Dave Blair

9. Biodiversity

Biodiversity accounts are used to identify change in the size and condition of populations and their habitat, threatening processes, and extinction risk. These accounts provide some of the information required to achieve the Aichi Biodiversity Targets, and especially Target 2, of the Convention on Biological Diversity (CBD 2014) and the Sustainable Development Goals 15.5 and 15.9 (UNDP 2015). These targets aim to place benefits of biodiversity into mainstream information systems for policy-makers.

In an initial assessment of biodiversity accounts, two main types of data were used: threatened species, and abundance and richness of a selected group of species (arboreal marsupials). Condition of biodiversity was assessed in terms of the number of species classified as threatened, the threat categories, and the change in categories over time. The change in threat category of a species represents change in the extinction risk of that species. These changes may be indicative of the direction of change in ecosystem condition related to more general biodiversity of the study area. There has been an increase in the number of critically endangered species in the last 5 years, with the addition to the lists of species of Leadbeater's Possum, Regent Honeyeater, Yellow-tufted Honeyeater, Round-leaf Pomaderis, and Mount Donna Buang Wingless Stonefly (Table 3).

Table 3. Change over time in the numbers of species in the study area listed under the Environmental Protection and Biodiversity Conservation Act 1999 (Cth) (ALA 2015)

	Regionally Extinct	Critically Endangered	Endangered	Vulnerable	Total
2000	2	0	12	14	28
2005	2	1	13	15	31
2010	2	1	13	18	34
2015	2	5	14	17	38
Net change	0	5	2	3	10

[Source: EPBC Act list of Threatened Fauna (DotE 2016), EPBC list of Threatened Flora (DotE 2016), and ALA 2015.]

Arboreal marsupials were selected for initial assessment of biodiversity and compilation of accounts because long-term monitoring data exist and occurrence of these species is strongly related to habitat variables that are influenced by disturbance events and forest age. The key habitat requirement for these animals is the presence of hollow-bearing trees.

One of the arboreal marsupial species is Leadbeater's Possum (*Gymnobelideus leadbeateri*), one of the faunal emblems of Victoria, which is listed as critically endangered. It requires a specific habitat of montane ash forests with large decayed trees with hollows to provide den sites, a dense understorey of *Acacia* species for food, and a complex vertical structure to provide transport routes through the forest. These characteristics of complex forest structure also provide the most diverse habitat for a large range of other species; hence, Leadbeater's Possum is indicative of other components of biodiversity.

Results of monitoring of arboreal marsupials over 28 years include:

- Significant positive relationship between animal occurrence and hollow-bearing trees.
- Old growth forests support significantly higher overall numbers of animals and species than regrowth forests (Figure 9).
- Numbers of animals have decreased significantly over time in all forest age classes, which represent the time period of regeneration (Figure 9).
- Numbers of hollow-bearing trees increase with forest age, with old growth having 2-3 times the number of hollow-bearing trees than regrowth forest.
- Loss of hollow-bearing trees in regrowth forest was four times the rate in old growth forest. Gain in hollow-bearing trees in regrowth forest was about three times less than in old growth forest.
- Regrowth forest post-logging lose more than half of the retained large trees within a few decades, with 17 per cent of sites no longer having any hollow-bearing trees.

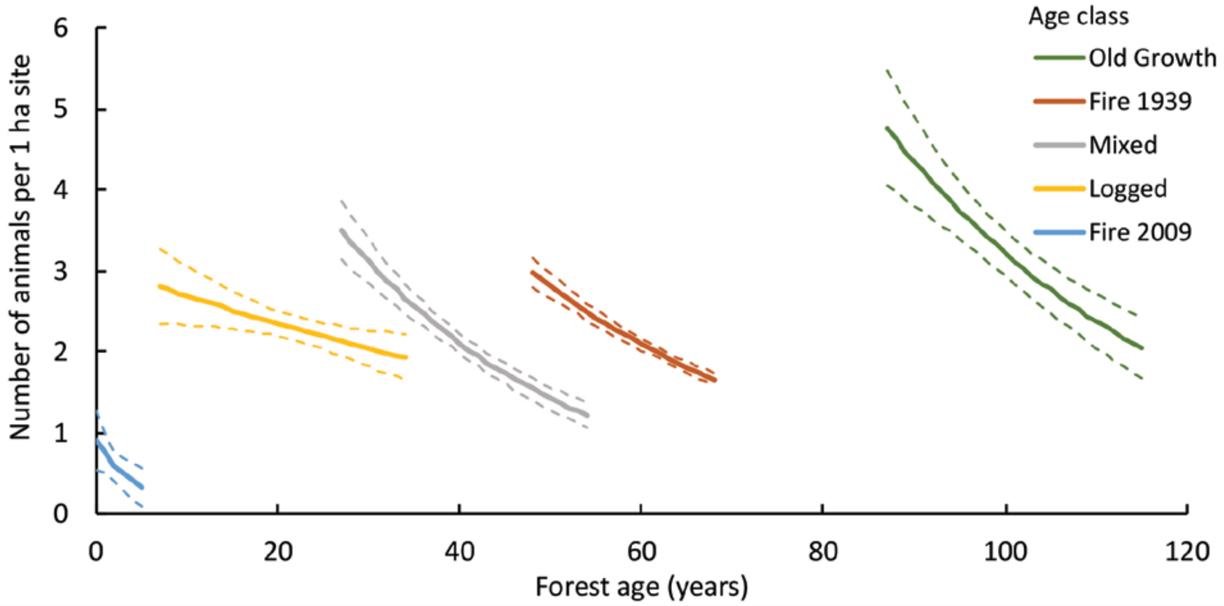


Figure 9. Change over time in numbers of arboreal marsupial animals within each forest age.

Sites in each of the five forest age classes have been monitored from 1987 to 2015, except age class Fire2009, where monitoring began in 2009. The monitoring data represent number of animals per 1 ha site each year, and how this has changed over the 28 years as forest age has increased. Solid lines represent the mean number and dashed lines are the upper and lower confidence limits. Monitoring sites were selected for their likely role as habitat for arboreal marsupials. Younger forest age classes have a relatively higher than average concentration of hollow-bearing trees, and are likely to over-represent the presence of arboreal marsupials. However, the data allow for comparison of change over time within specific age classes.

Recruitment of new hollow-bearing trees is unlikely in the next 40-50 years in the montane ash forest region because most of the forest extent is regrowth from the 1939 fire (trees currently 75 years old), or more recent fires and logging. Cavities first begin forming in Mountain Ash after about 120 years and exist for the time that the tree remains standing, whether alive or dead. Therefore, harvesting on rotations of less than 120 years results in no recruitment of hollow-bearing trees. **The key threatening process for arboreal marsupials is the accelerated loss of existing hollow-bearing trees and the impaired recruitment of new cohorts of these trees.**

Accounting for biodiversity at a regional scale has challenges in scaling up site data spatially across the region. Sites used for monitoring are selected to be suitable habitat for particular animals, and so are not necessarily sufficiently representative to provide quantitative information about abundance of animals spatially. Translating the benefit of biodiversity as a natural asset into a monetary value or determining its contribution to ecosystem services also presents many challenges, and has not been attempted for the purpose of this analysis. Species occurring within the study area clearly have value, as evidenced by the efforts made to conserve many of them and the tourist visitor numbers to the region.



Moth, Pobblebonk Frog, Soldier Beetle. Images: Lachlan McBurney, Damian Michael, Dave Blair

10. Synthesis of Ecosystem Accounts

10.1 Comparison of accounts

Ecosystem accounting consists of accounts for assets and the ecosystem services flowing from these assets. Ecosystem accounting allows for quantitative comparison of ecosystem assets and their ecosystem services across a landscape, and for assessing the contribution of different ecosystem assets to the economy and to other ecosystem services. The capacity of an ecosystem asset to generate ecosystem services is a function of the extent and condition of that ecosystem. This means that some uses of ecosystem assets (such as native timber harvesting) can impact on the other ecosystem services delivered (such as water run-off and filtration). Ecosystem accounting thus allows for analyses of the relative value of different land uses, as well as the trade-offs that occur between different natural resource priorities. Table 4 shows the supply of ecosystem services in the Central Highlands study area, quantified in terms of physical metrics and spatially disaggregated according to land cover and land use types.

Table 4. Supply of physical ecosystem services in the Central Highlands study area, average annual supply for the period 2010 to 2015

2010-2015		**Land cover**						
Ecosystem service	Units	built [a] / bare	open water	cross/ pasture/ horticulture	plantations	native open vegetation	native forest	Total
Area	Ha	31,624	4,361	57,993	36,316	29,624	575,737	735,655
	%	4.3	0.6	7.9	4.9	4.0	78.3	100.0
Provisioning services								
Water	GL yr^{-1}	0.99	0.14	0.14	0.12	0.22	3.39	3.97
Timber-sawlogs	m^3 yr^{-1}				129,800		304,920	
Timber-pulplogs	m^3 yr^{-1}				409,800		524,045	
Regulating services								
Agricultural production[b]	T							
Carbon sequestration[c]	MtC yr^{-1}				0.12		1.52	1.64
Cultural and recreational services								
Tourism[d]								

[a] *built includes low-density and semi-rural residential, parks and gardens*

[b] *the physical volumes of production of different crops, fruit, vegetables and livestock and livestock products are available for ABS statistical areas and can be estimated for the study region, but they have not been presented because the utility of adding these to a single measure in tonnes is doubtful. Monetary estimates of this service were generated*

[c] *carbon sequestration is equated with net carbon stock change because this is the metric that is valued in the Australian Government abatement scheme*

[d] *physical estimates of the tourism services were not made but monetary estimates were made*

Changes over time in the monetary values of ecosystem services reflect changes in both stocks and prices (Figure 10). For most of the time, water was the most valuable ecosystem service from the study area, but highly variable in relation to climate. For example, the decline in water provisioning service from 2012-15 was due to lower rainfall and hence lower inflows. Since 2014, the value of ecosystem services used in agricultural production have been greater. The trend in carbon sequestration reflects changes only in annual net carbon stocks because a constant carbon price, adjusted for inflation, was applied. Decreases in carbon sequestration occurred after fires in 2007 and 2009 due to emissions from combustion, but then increased in following years.

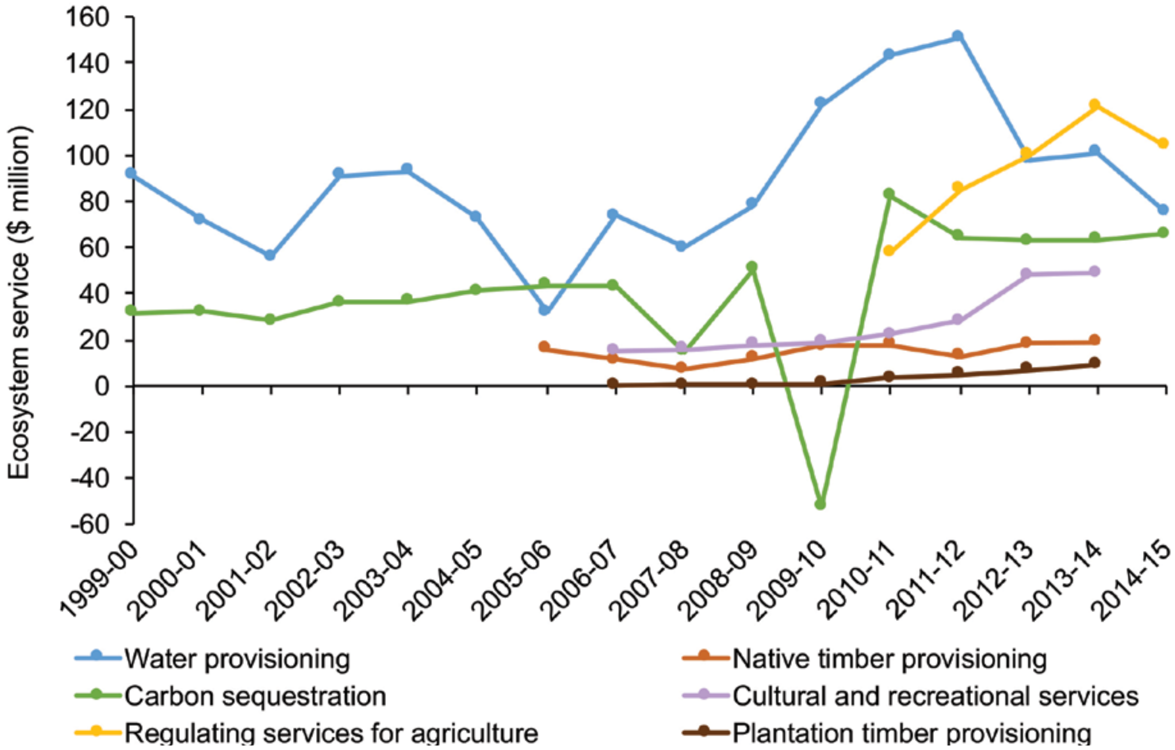


Figure 10. Value of ecosystem services generated in the Central Highlands study area.

Contributions of industries to the economy, based on the metric of IVA, show that agriculture, water supply and tourism are an order of magnitude above that of native forestry (Figure 11). IVA for plantation forestry is greater than that for native forestry, even though the area of land managed for plantations is 14 per cent of the area of native forest available for harvest, indicating substantially greater intensity of land use in the plantation sector. The decrease in IVA for water supply from 2012 to 2013 was due to the expenses associated with constructing the desalination plant. Although construction of this plant did not directly impact the volume of water supplied by the Central Highlands, it did cause a change in the price of water supplied by Melbourne Water and this reflected in the rising value of IVA for the subsequent two years. The IVA for tourism has increased since 2012 due mainly to increased numbers of international visitors, aided by the declining exchange rate post the global financial crisis and mining boom.

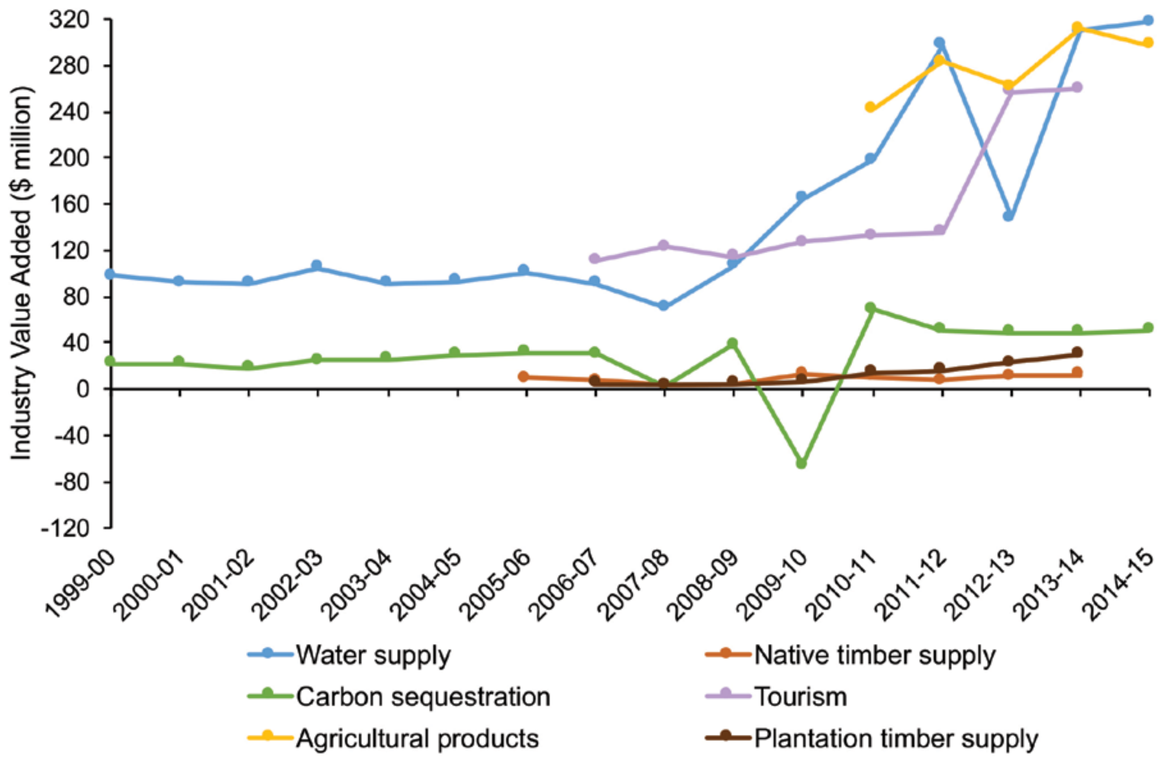


Figure 11. Industry Value Added generated in the Central Highlands study area contributing to the national economy.

Table 12 shows the different values associated with each stage in the ecosystem accounting model (see Figure 3) and the contribution of ecosystems services to each industry, and then the contributions of the industries to the economy, for example IVA. The relative values can be quantified at each of the points where trade-offs between conflicting land uses occur.

Table 12. Value of ecosystem services, human inputs, production and IVA for each industry ($ million 2013-14), as an example of quantifying the model in Figure 3.

Industry	Ecosystem services	Human inputs			Production	Benefits
		Intermediate consumption	Fixed capital consumption	Wages	Revenue	IVA
Agriculture	121	347	94	49	659	312
Water supply	101	601	187	54	911	310
Tourism	49				485	260
Carbon sequestration	63	14	2	15	63	49
Plantation timber	9	34	8	10	64	30
Native timber	19	50	3	8	62	12

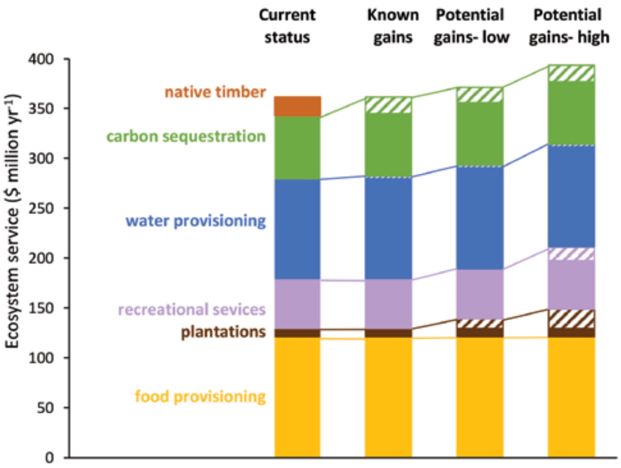
10.2 Trade-offs between ecosystem services

Trade-offs are required when the same area of land produces more than one ecosystem service or economic good or service, and their uses are incompatible. In addition, the use of one asset may affect the condition of other assets, or the same type of asset in different areas. Current examples of trade-offs in the Central Highlands relate to impacts of native forest harvesting on the condition of other ecosystem assets by reducing forest age.

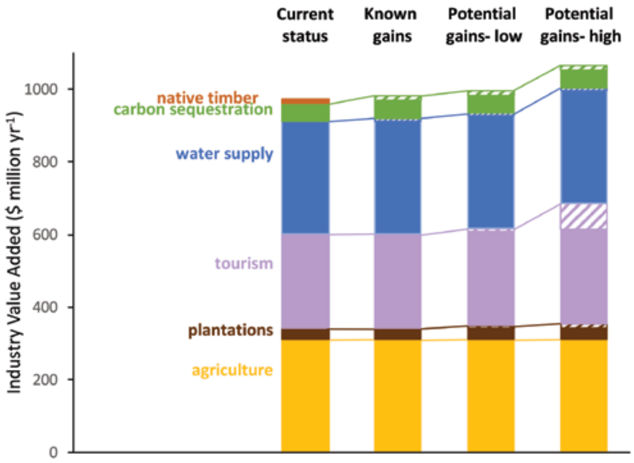
Land use activities of agriculture and settlements have caused major changes in ecosystem extent and condition in the past, which is seen by the comparison of land cover from pre-European settlement to present, with extensive clearing of open mixed forest and riparian shrubs (Eigenraam et al. 2013). While the area covered by settlements has been increasing, these changes have been relatively modest in recent decades. Within the study area, this expansion is not considered a threat to the supply of ecosystem services from forested areas.

Yellow-faced Honeyeater. Image: Dave Blair

Trade-offs in values of ecosystem services and IVA between native timber harvesting and other industries were derived from analyses of the counterfactual case: the difference in values of services if harvesting had not occurred. The area that has been harvested, during records of logging, within the Central Highlands study area is 115,421 ha. If native forest harvesting were phased out, this would result in losses of timber production. This would be largely offset by gains in carbon sequestration and water yield through continued forest growth. Accounting for carbon sequestration and water yield alone, ceasing native timber harvesting would result in a small net loss in ecosystem services (- $0.7 million yr^{-1}). However, ecosystem services for culture and recreation, plantation timber and agricultural production, which currently account for about half the total value of ecosystem services, would also very likely increase and more than account for this difference (Figure 12a). Accounting for the difference in IVA shows a net gain of +$8.5 million yr^{-1} from increased water supply and carbon sequestration minus the loss from native timber harvesting (Figure 12b), with potential gains likely to be significantly higher once all industries are included. Gains could also be expected in cultural and recreational services, which could be seen in increased numbers of tourists and tourism related expenditure. Plantation timber production may increase if it was the main industry to meet the demand for wood products. This could be through more intensive management or an expansion of area, for example onto agricultural land. Additionally, substantial gains would occur for habitat provisioning services for biodiversity through improved ecosystem condition of older forests, although it is difficult to ascribe an economic valuation figure.



(a) Ecosystem services



(b) Industry Value Added

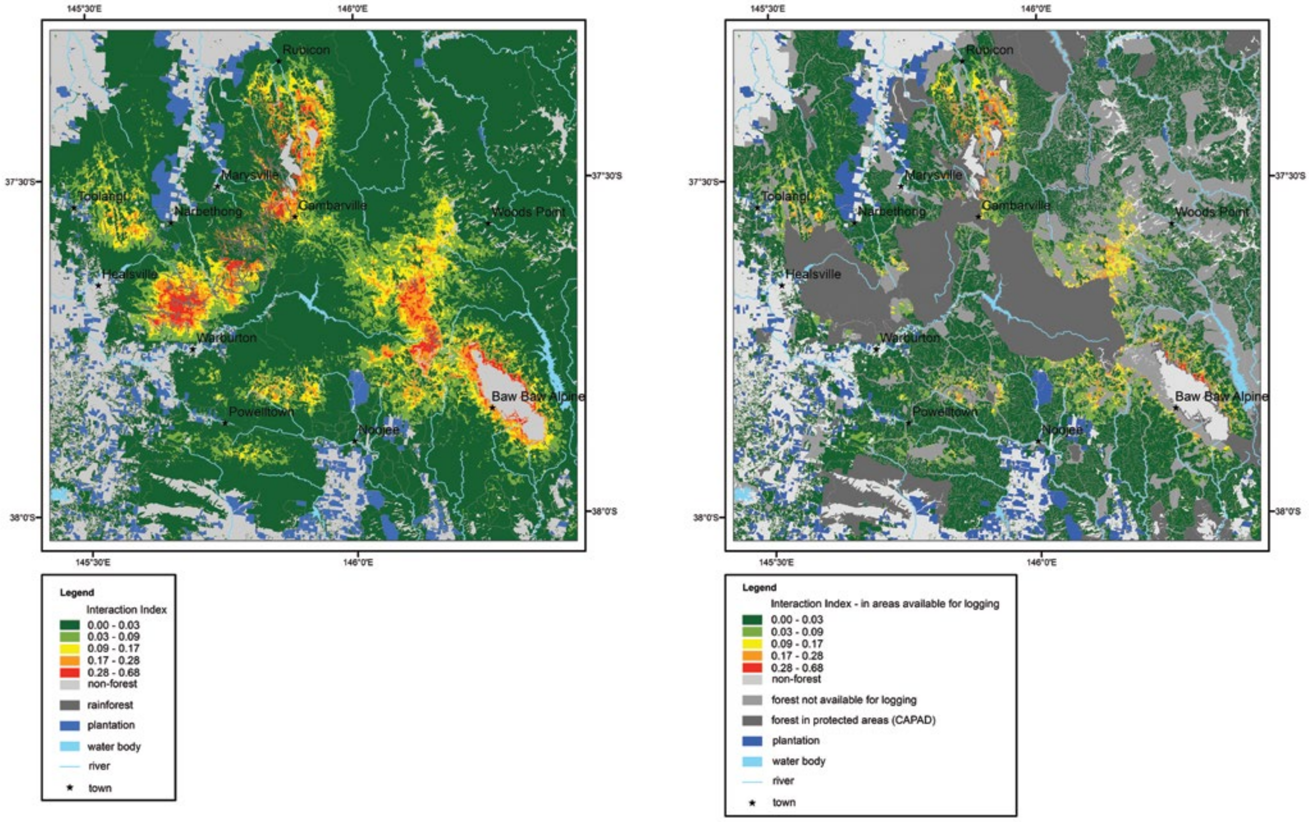
Figure 12. Value of ecosystem services and Industry Value Added (2013-14), and the potential changes if native forest harvesting were phased out.

Known gains in water yield and carbon sequestration.

Potential gains in culture and recreational services, and plantation timber production at an estimated low and high range.

10.3 Spatial distribution of ecosystem services

Spatial distributions were calculated for the values of water provisioning services, carbon storage, native timber provisioning, and a combined Interaction Index (Figure 13). The interaction of the highest combined values of these services, or 'hotspots', are identified in red. Use of these ecosystem services creates conflict in forest lands of the study area where harvesting of native timber reduces forest age, which decreases the condition of the forest for water yield and carbon storage. The area of conflict is shown within the current land management tenure where the forest is available for harvesting (Figure 13b). Mapping of these 'hotspots' identified the locations where trade-offs in the use of ecosystem services are required.



(a) All forest land in the study area

(b) Forest area with land management tenure available for logging.

Figure 13. Spatial distribution of the Interaction Index of values for water provisioning, native timber provisioning and carbon storage. Areas of highest values in red identify the 'hotspots', where maximum provisioning for native timber conflicts with maximising services of water provisioning and carbon storage.

11. Lessons for the development of ecosystem accounting

Ecosystem accounts present a unifying framework for existing diverse data for monitoring environmental and economic activities in a region. The consistent methodology allows evaluation of trade-offs between current or future uses of ecosystem assets and their services. They offer a compelling foundation for decision-making about natural resource management by presenting an integrated picture of benefits of ecosystems to society based on metrics that matter to human well-being. Application of ecosystem accounts has implications for better recognising ecosystem services, identifying trade-offs to improve ecosystem condition, and defining solutions to environmental-economic conflicts.

Implementing the SEEA ecosystem accounts in the Central Highlands has identified conceptual issues, data gaps and topics that require further consideration, and these include:

i. Biophysical data are collected mostly at the site scale, but this must be scaled up to the landscape scale to be used in accounts. This is one of the most critical processes in implementing ecosystem accounting.

ii. The experimental design for establishing monitoring systems and collecting site data is paramount so that the data can be scaled up successfully.

iii. Site and spatial data need to be linked through relationships derived between site data and ecosystem characteristics that can be presented spatially, from remote sensing, survey, or ground-based classifications. The most relevant ecological processes that determine these relationships for different ecosystems need to be identified.

iv. Ecological processes need to be defined in terms of functions over time, for example carbon accumulation, decomposition, mortality, reproduction, dispersal, and collapse of dead trees. These functions are used in deriving accounts of change over time in ecosystem assets.

v. Drivers of ecological change need to be identified and quantified, such as disturbance events and degradation processes. These drivers are important to understand the reasons for change in the past that are documented in the accounts, and to allow prediction of future changes.

vi. Economic data is generally for large spatial areas not related to biophysical characteristics. Methodological development is needed to improve spatial attribution of economic and social data to match environmental data. More detailed economic data that is region and industry specific would be valuable.

vii. Selecting the boundary for a study area is complex because the many sources of data integrated in the accounts use different boundaries, such as natural resource management area, catchments, local government, statistical areas, ecosystem types and land use regions. No single boundary will accommodate all the different sources of data. Furthermore, social, geographical and policy considerations all play a role in the selection of appropriate boundaries. Thus, consideration should be given to the appropriate boundaries and how these may impact findings, particularly in terms of how the choice of study area can best address the policy questions that need to be answered.

Old growth forest in the O'Shannassy catchment. Image: Luke Chamberlain

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Further information:

http://www.nespthreatenedspecies.edu.au/

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