Technical report on physical and monetary supply and use accounts for the Gunbower-Koondrook-Perricoota Forest Icon Site

A report from the Land and Ecosystem Accounts Project

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Contents

Tables

Figures

Boxes

Acronyms

Acronym	Definition
AGB	Above-ground biomass
AusEcoModels Framework	Australian Ecosystem Models Framework
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWE	Department of Agriculture, Water and the Environment
EVC	Ecological vegetation class
GKP	Gunbower-Koondrook-Perricoota Forest Icon Site
IDEEA	Institute for Development of Environmental-Economic Accounting
IUCN	International Union for Conservation of Nature
LEAP	Land and Ecosystem Accounts Project
MDBA	Murray−Darling Basin Authority
Marsden Jacob	Marsden Jacob Associates
Project	Valuing Parks Case Study Project
SEEA EA	System of Environmental-Economic Accounting −Ecosystem Accounting
SNA	System of National Accounts
TLM	The Living Murray
UNCEEA	United Nations Committee of Experts on Environmental-Economic Accounting

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The Valuing Parks Case Study Project (the Project) is part of the Land and Ecosystem Accounts Project (LEAP), progressing under the national strategy for a common national approach to environmental-economic accounting (IJSC 2018), governed by the Environmental-Economic Accounts Board. Leaders of each sub-project are underlined.

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Executive Summary

Ecosystem services are transactions between ecosystems and economic units such as households, government, and industry. This technical report describes the method and results for the measurement of a subset of the ecosystem services that the Gunbower-Koondrook-Perricoota Forest Icon Site (GKP) provides, consistent with the United Nations System of Environmental Economic Accounting. These ecosystem services were measured quantitatively and qualitatively for the project for 2010 and 2015, including:

- provisioning services – biomass for timber and firewood (quantitatively), floral resources for honey production (quantitatively) and floral resources for hive building (qualitatively)
- regulating services – global carbon sequestration and retention (quantitatively), water flow regulation (qualitatively)
- cultural services – ecosystem services and First Nations (qualitatively) and recreation-related services (quantitatively).

Ecosystem and species appreciation flows were also quantified despite not meeting the requirements for inclusion as an ecosystem service under the United Nations System of Environmental-Economic Accounting framework (SEEA EA).

The key project findings include:

- 47,988 total tonnes of biomass for timber were harvested across the GKP in 2010, dropping to 9,027 tonnes in 2015. Biomass for timber was only harvested from the 'inland floodplain eucalypt forests and woodlands' ecosystem type.
- Timber harvested in 2010 had a total accounting monetary value of around $868,000. Of this total, $66,000 was supplied by the Gunbower Forest and $802,000 by the Koondrook-Perricoota Forest.
- In 2010 and 2015, the total firewood yield across GKP was 74,131 tonnes and 57,937 tonnes, respectively. All firewood was harvested from the 'inland floodplain eucalypt forests and woodlands' ecosystem type and is allocated to the local firewood industry.
- Total biomass for firewood harvested in 2010 has an accounting monetary value of around $1,482,000. The total accounting monetary value of harvest from GKP in 2015 is around $1,159,000.
- The total supply of carbon sequestration services was 1,022,807 tonnes in 2010 and 1,030,771 tonnes in 2015.
- The 2010 total monetary supply and use of carbon sequestration relying on exchange values from the World Bank Carbon Pricing Dashboard was around $71 million. Inland floodplain eucalypt forests and woodlands supplied around $25.1 million and $42.2 million of monetary supply and use across Gunbower Forest and Koondrook-Perricoota Forest respectively.
- The 2015 total monetary supply and use of carbon sequestration relying on ACCU exchange values from the World Bank Carbon Pricing Dashboard was around $94

million. Inland floodplain eucalypt forests and woodlands supplied around $35.6 million and $53.6 million of monetary supply and use across Gunbower Forest and Koondrook-Perricoota Forest respectively.

- There was a total of 44,812 and 28,597 ha of habitat suitable for 8 focal species in 2010 and 2015 respectively.
- Between 2010 and 2015 there was a reduction in area of habitat for the eight focal species across the whole GKP site. The greatest reduction in habitat for these focal species was 11,909 ha from 'inland floodplain eucalypt forests and woodlands' ecosystem type in Koondrook Perricoota. The largest decrease in habitat for the 8 focal species in Gunbower was 2,929 ha from the 'inland floodplain eucalypt forests and woodlands' ecosystem type.
- Ecosystem and species appreciation in 2010 had a total accounting monetary value of around $150 million. The 'inland floodplain eucalypt forests and woodland' ecosystem type provides the largest proportion of value in both 2010 and 2015. In 2010, this ecosystem type provided around $46.5 million of accounting monetary value from Gunbower and around $71.2 million from the Koondrook-Perricoota.
- In 2015, the total ecosystem and species appreciation accounting monetary value fell to around $113 million. In 2015, the 'inland floodplain eucalypt forests and woodlands' ecosystem type provided around $30.4 million of accounting monetary value from the Gunbower and around $45.2 million from the Koondrook-Perricoota.
- In 2010, total visit days to Gunbower and Koondrook-Perricoota are estimated at 211,000. In 2015, total visit days to Gunbower and Koondrook-Perricoota are estimated at 340,000. Around three-quarters of total visit days are in Gunbower National Park.
- In 2010, consumption expenditure attributable to Gunbower and Koondrook-Perricoota is estimated at $14.3 million. In 2015, consumption expenditure attributable to Gunbower and Koondrook-Perricoota is estimated at $21.7 million. Around 72% of total consumption expenditure is again attributable to Gunbower National Park.

1 Introduction

The Valuing Parks Case Study Project (the Project) is part of the Land and Ecosystem Accounts Project (LEAP), progressing under the national strategy for a common national approach to environmental-economic accounting (IJSC 2018). The objectives of the Project are to:

- describe the values of the case study sites in accordance with the draft United Nations (UN) System of Environmental Economic Accounts – Ecosystem Accounts (SEEA-EA) framework (UNCEEA 2020; United Nations 2014)
- illustrate applicability of ecosystem accounting to support a wide range of decision making
- involve local stakeholder engagement
- generate lessons that can be fed into future ecosystem accounts, including by building and illustrating an operational accounting framework for ecosystems.

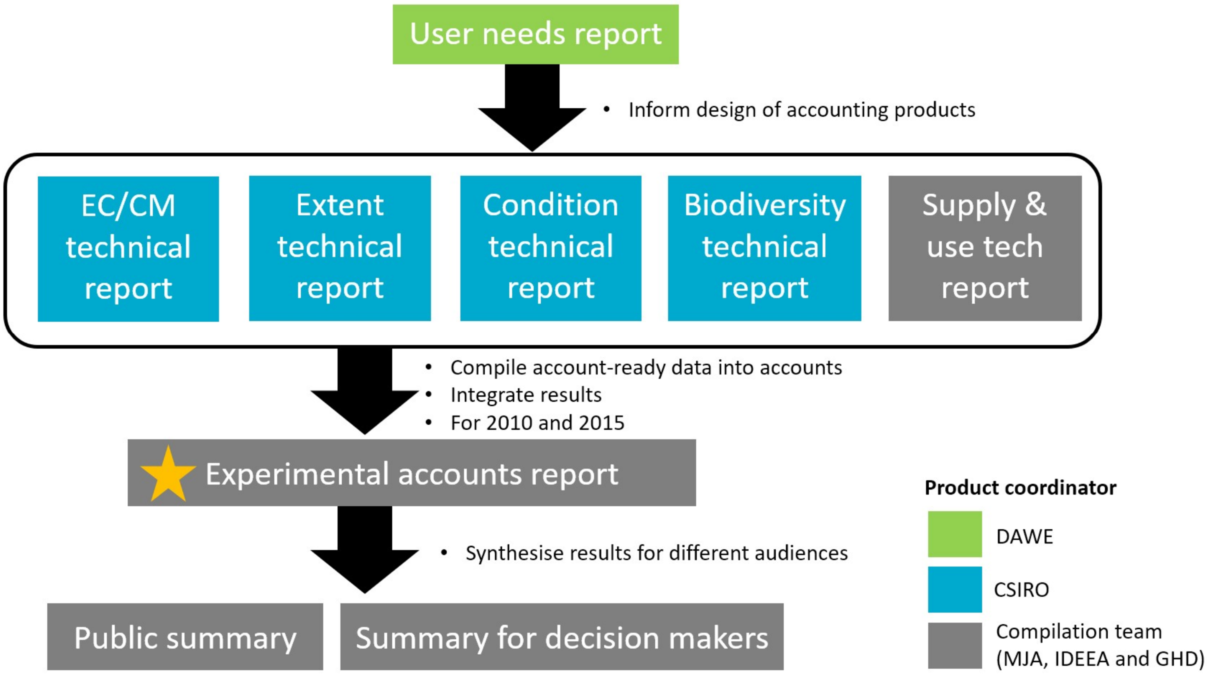
The Project delivered a series of ecosystem accounts, covering ecosystem extent and condition, biodiversity, the flow of a set of ecosystem services and the benefits or value (monetary and non-monetary) these services provide. The case study site selected was Gunbower-Koondrook-Perricoota Forest Icon Site (GKP) in partnership with the Murray-Darling Basin Authority (MDBA).

This report is one output of the GKP case study, which was led by the Department of Agriculture, Water and the Environment, in partnership with the MDBA; Commonwealth Scientific and Industrial Research Organisation (CSIRO); Department of Industry, Science, Energy and Resources (DISER); Marsden Jacob Associates; GHD; and Institute for Development of Environmental-Economic Accounting (IDEEA) Group. Other Commonwealth, state/territory and local jurisdictional agencies, private sector entities and academia were involved where relevant.

Figure 1 provides an overview of the suite of reports for GKP. This report is the technical report on physical and monetary supply and use accounts for the Gunbower-Koondrook-Perricoota Forest Icon Site. The technical report supplements the physical and monetary supply and use accounts presented in the integrated accounts report (McLeod et al., 2021). This technical report includes:

- a set of physical and monetary supply and use accounts using account-ready data on ecosystem extent, ecosystem condition, and biodiversity
- summary literature reviews for the physical and monetary supply and use accounts presented
- data tables and figures to supplement the summary account tables in the Gunbower-Koondrook-Perricoota – Environmental-Economic Accounting: Experimental Accounts Report

Figure 1 Suite of reports delivered in the Valuing Parks Case Study Project



Note: This report (led by the ecosystem accounting and analysis sub-project) is indicated by an orange star. EC/CM = ecosystem classification and conceptual models.

2 Context

2.1 The accounting framework

Ecosystem physical and monetary supply and use accounts are a component of the core ecosystem accounting framework (Figure 2) (Eigenraam & Obst, 2018).

The ecosystem accounting framework presents an approach to bridging ecosystems and the economy by conceptualising the ecosystems as an asset. These assets can be differentiated by their type (for example ecosystem type or further by their specific characteristics) and are then measured according to their quantity (extent or area) and quality (condition).

Each ecosystem asset can supply multiple ecosystem services which are, in turn, used in the production of benefits. The flow of services from an ecosystem to a beneficiary (economic units such as households, governments, and businesses) is treated as a transaction which can be recorded in physical and monetary units.

The ecosystem accounting framework, the objectives of ecosystem accounting, accounting outputs and the interpretation of accounting outputs are introduced in the Gunbower-Koondrook-Perricoota – Environmental-Economic Accounting: Experimental Accounts Report (McLeod et al., 2021). Readers not familiar with methods for developing ecosystem physical and monetary supply and use accounts are also encouraged to read the final draft of the SEEA EA (United Nations Department of Economic and Social Affairs Statistics Division, 2021) for background.

Figure 2 Core ecosystem accounting framework

Note: Pressures can also be integrated into the framework to provide another link between the economy/society and the environment.
Source: (Eigenraam & Obst, 2018)

2.2 Ecosystem physical and monetary supply and use accounts

This section provides a short introduction to ecosystem physical and monetary supply and use accounts. Account presentation and the framework for ecosystem physical and monetary supply and use accounts are set out in the System of Environmental-Economic Accounting—Ecosystem Accounting: Final Draft section 7 (physical supply and use) and 8 (monetary valuation) (UNCEEA, 2021a). Readers are encouraged to refer to the System of Environmental-Economic Accounting—Ecosystem Accounting: Final Draft for more detail.

An example of physical and monetary supply and use accounts is shown in Table 1 and Table 2. The structures of the Tables in Table 1 and Table 2 are an application of the supply and use table (SUT) as described in the System of National Accounts (SNA) and the SEEA Central Framework to flows of ecosystem services in physical and monetary terms (UNCEEA, 2021a).

A key principle of the supply and use table structure (as shown in Table 1 and Table 2) is that the quantity of supply of ecosystem services is equal to use in an accounting period. The unit of measure is also the same (United Nations Department of Economic and Social Affairs Statistics Division, 2021).

All supply and use tables in this report include a statement on the confidence in the data (for physical supply and use) and the estimate (for monetary supply and use), based on the opinions of the authors.

Table 1 Biomass for timber physical supply and use table, GKP, 2010 and 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply /Use	**Units**	**Household**	**Government**	**Industries**	**Fire-intolerant *Callitris* woodlands**	**Inland floodplain eucalypt forests and woodlands**	**Wetlands**	**Cultivated areas**	**Re-sprouter temperate and subtropical eucalypt woodlands**	**Lowland Streams**	**Fire-intolerant *Callitris* woodlands**	**Inland floodplain eucalypt forests and woodlands**	**Wetlands**	**Cultivated areas**	**Re-sprouter temperate and subtropical eucalypt woodlands**	**Lowland Streams**
2010																
Supply	tonnes				-	962	-	-	-	-	-	47,026	-		-	-
Use	tonnes			47,988												
2015																
Supply	tonnes				-	432	-	-	-		-	8,595	-		-	-
Use	tonnes			9,027												

Note: Supply and use of biomass for firewood is derived from 2010 and 2015 yields. Yield data was measured in tonnes and m^3 across specific coupes (Ha). Confidence in data is high. Firewood yield data from NSW Forest Corp was defined by tonne and m^3 within different harvesting areas in Koondrook and Perricoota forests. Yield data from Victorian Department of Jobs, Precincts and Regions was averaged and contains some uncertainty. Estimates can be improved with finer scale collection of firewood yield data within the harvested coupes that identifies go and no go areas, especially within NSW forestry coupes. '–' = 0

Source: Data from Victorian Department of Jobs, Precincts and Regions, 2021 and NSW Forest Corp, 2021

Table 2 Biomass for timber monetary supply and use summary table, GKP, 2010 and 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply/Use	Units	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
2010																
Supply	$ AUD				-	66,000	-	-	-	-	-	802,000	-	-	-	-
Use	$ AUD			868,000												
2015																
Supply	$ AUD				-	30,000	-	-	-	-	-	393,000	-	-	-	-
Use	$ AUD			423,000												

Note: Residual rents of biomass for timber are derived from 2010 and 2015 royalty estimates and are presented in nominal terms. Residual rents are the total monetary output less the costs of timber harvest and depreciation. Confidence in data is high. Sawlog royalties have been adjusted based on evidence from Victorian Department of Jobs, Precincts and Regions and New South Wales Department of Primary Industries. Yield values from Gunbower forest include some uncertainty and are averages across the thinned region (Ha). Estimates can be improved with finer scale collection of timber yield and related variable and fixed cost data. '–' = 0

Source: Data from (Victorian Department of Jobs, Precincts and Regions, 2021 and NSW Department of Primary Industries, 2017)

2.2.1 Supply Accounts

Supply is generally based on ecosystem types (as shown in Table 1 and Table 2). In Chapter 9 of the companion accounts report (McLeod et al., 2021), this project also reports flow of ecosystem services by ecosystem states and report bundles of ecosystem services, as in (Lavorel et al., 2015). Where an ecosystem service is jointly supplied by a combination of ecosystems, supply is apportioned to individual assets using spatial allocation methods or measurement conventions (United Nations Department of Economic and Social Affairs Statistics Division, 2021).

The nested classification of ecosystem types, states and expressions for GKP is provided in Table 3. This is the foundation for the accounting presentations made in this report. Information on extent, condition and services will be presented by ecosystem type, and in some cases by ecosystem state and expression.

Table 3 Ecosystem types, states and expressions in the Gunbower-Koondrook-Perricoota Forest Icon Site

Umbrella class	Ecosystem type	Ecosystem state	Ecosystem expression
Eucalypt woodlands	Inland floodplain eucalypt forests and woodlands	Reference*	Mature floodplain eucalypt forests and woodlands
			Reduced tree canopy with wetland, grassland or chenopod understorey
			Dense seedling eucalypts
			Dense pole-stage eucalypt stands
		Modified: Reduced tree canopy over invaded understorey*	Mature floodplain eucalypt forests and woodlands
			Reduced tree canopy over invaded understorey
			Dense seedling eucalypts with invaded understorey
			Dense pole-stage eucalypt stands
		Modified: Invaded mature floodplain eucalypt forests and woodlands*	Invaded mature floodplain eucalypt forests and woodlands
			Reduced tree canopy over invaded understorey
			Dense seedling eucalypts with invaded understorey
			Dense pole-stage eucalypt stands
		Modified: Halophytic state*	Reduced tree canopy with halophytic and invaded understorey§
			Dense seedling eucalypts with invaded understorey
			Invaded halophytic shrubland

Umbrella class	Ecosystem type	Ecosystem state	Ecosystem expression
	Re-sprouter temperate and subtropical eucalypt woodlands	Reference	Grey box grassy woodlands
			Grey box shrub-grass woodlands
		Modified: Grey box woodlands with exotic understorey*	Grey box grassy woodlands with exotic understorey
			Grey box shrub-grass woodlands with denuded understorey
Callitris forests and woodlands	Fire-intolerant *Callitris* woodlands	Reference	Sandhill pine woodlands
		Modified: Low-rise sandhill pine woodlands*	Senescent *Allocasuarina* over invaded understorey
		Modified: High-rise sandhill pine woodlands*	Denuded canopy and no understorey strata
Sedgelands, rushlands and herblands	Wetlands	Reference	Permanent wet
			Permanent dry
			Semi-permanent wet
			Semi-permanent dry
			Temporary wet
			Temporary dry
		Modified: High-condition wetlands*	Permanent wet (high-condition)
			Semi-permanent wet (high-condition)
			Temporary wet (high-condition)
			Mudflat (high-condition)
		Modified: Moderate-condition wetlands*	Permanent wet (moderate-condition)
			Semi-permanent wet (moderate-condition)
			Temporary wet (moderate-condition)
			Mudflat (high-condition)
			Mudflat (moderate-condition)
			Dirt
		Modified: Low-condition wetlands*	Wet (low-condition)
			Mudflat (low-condition)
			Dirt
Freshwater aquatic ecosystems	Lowland streams	Reference	River Murray main channel
		Modified: Managed flows*	River Murray main channel
			Irrigation supply channel

Note: Also shown are the umbrella classes under which each ecosystem type sits. Archetype models in the AusEcoModels Framework (Richards et al. 2020) serve as general templates for ecosystem types shown here.
*States that occurred at GKP in 2010 and 2015.
Source: (Richards et al. 2021c)

In addition to the 5 ecosystem types in the GKP ecosystem classification (Table 3), some areas were classified as cultivated areas, which occurred mostly on the boundary of the icon site and as small areas within GKP. This ecosystem type did not have defined states or expressions, and was identified by the CSIRO-developed ePaddocks™ product which identifies paddock boundaries across the grain production areas of Australia (Diakogiannis et al. 2020; Waldner and Diakogiannis 2019).

In total, 6 ecosystem types and 1 unclassified class are within the accounting area. Please refer to **Table 8** in the accounts report (McLeod et al., 2021) for an ecosystem account and **Figure 7** in the accounts report (McLeod et al., 2021) for maps of ecosystem extent in 2010 and 2015. 'Inland floodplain eucalypt forests and woodlands' was the dominant ecosystem type in 2010 and 2015 making up approximately 85% of the total area in both years. Wetlands were the second most dominant with a share of approximately 10% in both years. Cultivated areas and fire-intolerant *Callitris* woodlands had the lowest proportion of total area in both years (McLeod et al., 2021).

2.2.2 Use Accounts

Use records the consumption of the ecosystem service supplied by economic units by specific users. Users of final ecosystem services are households, government and / or industry and users of intermediate services are other ecosystem assets. Where there is a sequence of intermediate services and final ecosystem services, recording the supply and use of each service avoids double counting. For example, for pollination and biomass provisioning services, the supply and use of pollination services from one ecosystem (river red gum forest where pollinators live) to another (orchards where pollination occurs) is recorded as a supply and use of an intermediate service. Supply of the intermediate service of pollination is attributed to the forest and there is a use of pollination services by the farmland (as an input to its supply of final ecosystem services) and supply of biomass provisioning services (United Nations Department of Economic and Social Affairs Statistics Division, 2021).

Cultural services, like recreation, involve an interaction between people and ecosystems. Quantification of the services measures the type, number and/or quality of the interaction. For example, recreation-related services are commonly quantified using the number of visits to a specific natural location. While these measures are not a direct quantification of the ecosystem contribution, they are currently considered a suitable proxy that can be improved by taking into consideration as far as possible the number and length of time of interactions with specific features and characteristics of the ecosystems concerned (United Nations Department of Economic and Social Affairs Statistics Division, 2021).

2.3 Monetary supply and use accounts

In ecosystem accounting, the primary motivation for monetary valuation using a common monetary unit or numeraire is to be able to make comparisons of different ecosystem services and ecosystem assets that are consistent with standard measures of products and assets from the national accounts (United Nations Department of Economic and Social Affairs Statistics Division, 2021). Monetary valuation is needed to be able to measure the use, gain and loss of asset stocks and their flows using a common unit of measure, and so that these values are consistent with Australian equivalent values to International Financial Reporting Standards (AIFRS) and the requirements of the *Financial Management Act 1994*.

Monetary supply and use in SEEA accounts are valued based on exchange values. "In national accounting, the entries in the accounts in monetary terms reflect their exchange values as defined in the System of National Accounts (SNA). Exchange values are the values at which goods, services, labour, or assets are in fact exchanged or else could be exchanged for cash" (2008 SNA, para. 3.118).

Chapters 8-9 in the SEEA EA (United Nations Department of Economic and Social Affairs Statistics Division, 2021) provides current guidance on techniques for valuing transactions in ecosystem services. There is strong preference for accounting purposes in using methods that translate observable and revealed prices and costs (i.e., for related or similar goods and services) into the values required for accounting purposes. In order of preference the methods for measuring monetary supply and use are: (1) those where the price is directly observable through market exchanges (2) those where prices are obtained from markets for similar goods and services (proxy markets) (3) those where the prices (and associated values) are embodied in market transactions (reflected in the residual resource rent approach, see Figure 3) (4) those where the prices are based on revealed expenditures (costs) in related goods and services and (5) those where the prices are based on hypothetical expenditures or markets.

Current SEEA guidance (United Nations Department of Economic and Social Affairs Statistics Division, 2021) recognise that monetary values in environmental-economic accounts will not fully reflect the importance of ecosystems for people and the economy. Assessing the importance of ecosystems will therefore require consideration of a wide range of information beyond data on the monetary value of ecosystems and their services. For example, the companion technical reports (Mokany K et al., (2021a) ; Richards AE et al., 2021b; Richards AE et al., 2021a; Richards AE et al., 2021c) and the main accounts report (McLeod et al., 2021) in this project are a demonstration of how biophysical measurements can also be used to assess the importance of ecosystems.

Figure 3 Exchange based residual rents approach

Output (sales of extracted environmental assets at basic prices, includes all subsidies on products, excludes taxes on products)

Less Operating costs

Intermediate consumption (input costs of goods and services at purchasers' prices, including taxes on products)

Compensation of employees (input costs for labour)

Other taxes on production plus Other subsidies on production

Equals Gross Operating Surplus – SNA basis (a)

  Less Specific subsidies on extraction

    Plus Specific taxes on extraction

Equals Gross Operating Surplus – for the derivation of resource rent

Less User costs of produced assets

Consumption of fixed capital (depreciation) + Return to produced assets

Equals Resource rent

Depletion + Net return to environmental assets (b)

(a) Strictly this accounting identity also includes Gross Mixed Income (the surplus earned by unincorporated enterprises) and should be adjusted for net taxes and subsidies on production. These details do not affect the logic of the explanation here.

(b) In principle the net return to environmental assets derived here also incorporates a return to other non-produced assets (e.g. marketing assets and brands) as these assets also play a role in generating the operating surplus. These returns are ignored in the formulation described here.

3 Accounting area

GKP is located on the Murray River north-west of Echuca and covers an area of 56,020 ha across the Victorian and NSW sides of the river (Figure 3). In Victoria, Gunbower Forest (21,066 ha) is part national park (gazetted in 2010 and managed by Parks Victoria) and part state forest (managed by the Victorian Department of Environment, Land, Water & Planning); in NSW, Koondrook-Perricoota Forest (34,954 ha) is made up of several state forests managed by NSW Forestry Corporation. Pollack Swamp is a 200 ha flora and fauna reserve in the north of Koondrook-Perricoota Forest, collaboratively managed by Forest Corporation and NSW Office of Environment.

Through Ramsar listing of the Gunbower site in 1982 and the *Water Act 2007*, the Australian Government also has a stake in management, which can be exercised through the Murray–Darling Basin Authority (MDBA). The Australian Government also has powers under the *Environment Protection and Biodiversity Conservation Act 1999*, and possibly others, which could be applied to the area.

The Gunbower Forest Wetlands site meets four of the nine Ramsar criteria:

- Criterion 1: Gunbower is part of the second largest river red gum forest in the Murray Darling Basin (the largest being Barmah-Millewa Forest). The size and intact nature of this forested floodplain makes it one of the best representatives of a freshwater, tree-dominated wetland type in the bioregion. Gunbower is also internationally important due to its hydrology as it forms an extensive area of intact floodplain between the Murray River and Gunbower Creek, and is one of few such areas with native vegetation in the bioregion.
- Criterion 2: Five threatened species listed at the national and / or international level have been recorded within the boundary of the Gunbower Forest Ramsar site: Australasian bittern (Botaurus poiciloptilus); Murray cod (Maccullochella peelii); silver perch (Bidyanus bidyanus); river swamp wallaby grass (Amphibromus fluitans); and winged peppercress (Lepidium monoplocoides).
- Criterion 4: The site meets this criterion based on the role of the site in supporting breeding of wetland birds, frogs, turtles and fish during periods of inundation. A total of 48 species of wetland bird have been recorded breeding within the Gunbower Ramsar site, which is over 70 per cent of the total wetland bird species richness for the site. In addition, there are records of fish spawning in wetland and stream habitats as well as at least two species of turtle and six species of frog.
- Criterion 8: The site provides migratory routes for fish between habitat in the Murray River and floodplains; with Gunbower Creek an important passage for native fish. Native fish of the Murray River main channel utilise anabranch and flood runner channels when they are available. Native fish move into off-stream areas on rising flows, and make refuge movements into deeper waters during low flow periods. Many species spawn on the floodplains. Tagged fish have been recorded moving large distances from the site (up to 300 kilometres upstream and 900 kilometres downstream), which is indicative of pre- and post-spawning behaviour. River red gum forests make a

significant contribution to in-stream nutrient accumulation and productivity through litterfall and provide important shelter in the form of coarse woody debris and shaded water.

GKP is also one of six icon sites that are regularly monitored under The Living Murray (TLM) program, established in 2002 to maintain their ecological health. Icon sites in the TLM program are identified as priority environmental assets in the long-term watering plans developed by Murray-Darling Basin state governments as part of the Basin Plan (MDBA 2018). The North Central Catchment Management Authority manages Gunbower Forest, conducts monitoring under TLM and coordinates the delivery of environmental water. NSW Forestry Corporation is the Koondrook–Perricoota Icon Site manager and coordinates the delivery of environmental water to Koondrook-Perricoota Forest.

Figure 4 Map of Gunbower-Koondrook-Perricoota Forest Icon Site.

Note: Extracted from (Richards et al. 2021a)

GKP sits within the Murray-Darling Basin. The rivers and wetlands within the Basin have long supported people. Many rivers and wetlands have been modified to provide water for agriculture, towns and industries. Extraction of water from the Basin and modifications to endogenous flow regimes (regulated by climate and Indigenous management) have adversely affected many ecosystems. These modifications include a reduced frequency, magnitude and/or duration of flows, resulting in fewer large overbank flows, and a switch to higher flows in summer and lower flows in winter and spring compared to pre-river regulation (MDBA 2019). These changes have altered the connectivity of rivers to floodplains and to groundwater, with this impacting the health, abundance and range of water-dependent species (MDBA 2019).

In 2012 the Murray-Darling Basin Plan (the Basin Plan; MDBA 2012a) was introduced with the aim of returning the Basin to a healthy working system by improving its environment, while balancing social and economic needs in a sustainable way. The Basin Plan builds on the work started under the TLM and sets out the sustainable diversion limit (maximum quantities of water that can be sustainably taken from the Basin) and environmental water (the share of water that can be used to achieve environmental outcomes). The Basin-wide environmental watering strategy complements the Basin Plan and sets out its long-term environmental objectives (MDBA 2019). These include:

- improve connections along rivers and between rivers and their floodplains
- maintain the extent and improve the condition of native vegetation (river red gum, black box and coolibah forest and woodlands, wetlands)
- maintain current species diversity of waterbirds and improve breeding success and numbers
- maintain current species diversity of fish, extend distributions and improve breeding success and numbers.

Underneath the Basin-wide environmental watering strategy are environmental water management plans for Gunbower Forest (MDBA 2012b) and Koondrook-Perricoota Forest (Hale and SKM 2011). These plans establish priorities for use of environmental water at GKP, setting the ecological objectives and targets and site-specific watering regimes for the two areas, as well as environmental works and water delivery arrangements. An example of environmental works is the Torrumbarry Cutting, which has been constructed as part of TLM works program to deliver water to Koondrook-Perricoota Forest from the Torrumbarry weir pool (Hale and SKM 2011). Ecological objectives in these detailed plans are aligned with those prescribed under the Basin-wide environmental watering strategy.

Environmental watering is helping to sustain the condition of Gunbower Forest, based on a 10-year assessment of TLM monitoring data for GKP against ecological objectives from 2006–07 to 2016–17 (MDBA 2018), which spans the implementation of the Basin Plan and associated environmental watering. However, the absence of larger floodplain watering events (and minimal environmental water delivery) at Koondrook-Perricoota Forest has meant that most ecological objectives have not been met over the 10-year period (MDBA 2018).

TLM monitoring data collected at GKP include:

- stand condition monitoring of communities dominated by *Eucalyptus camaldulensis* (river red gum) and *E. largiflorens* (black box) (e.g. Bennetts and Jolly 2017)

- aerial waterbird surveys (e.g. Bino et al. 2014)
- fish surveys (e.g. Bloink et al. 2018)
- wetland and understorey plant richness and abundance (e.g. Bennetts 2014b)
- woodland bird surveys (e.g. Webster 2017; Webster 2018)
- water quality monitoring (G. Smith, pers. comm)

4 Ecosystem services accounting

4.1 Introduction

Ecosystem services accounting involves recording the flows of services provided by an ecosystem, and the use of those services by economic units, i.e. households, governments and businesses. The measurement of ecosystem services can be undertaken in physical and monetary terms and be used to reveal how the flows of ecosystem services relate to the health of the ecosystem and how human activity may be influencing the level of services. Further, ecosystem services can be measured over time to understand trends in the relationship between different economic units and ecosystems and the relative contribution of ecosystems to different social and economic benefits and broader well-being. Priority areas for management can be identified by comparing ecosystem services across spatial areas.

Importantly, flows of ecosystem services are connected to the extent and condition of ecosystem assets (Richards AE et al., 2021a) and thus the methods used to classify and record both extent and condition (Richards AE et al., 2021b; Richards AE et al., 2021a) need to underpin the measurement of ecosystem services. Often scientific endeavours focus on only one aspect of the ecosystems, say extent, condition or services. Consequently, combining and interpreting the results can be quite challenging. This project incorporated ecosystem accounting principles and an ecological conceptual framework to assist coherence across accounting elements. The ecological approach utilised conceptual models that endeavoured to develop a conceptual framework (consistent with accounting principles) to assist with coherence across accounting elements and is also a scientific basis for change attribution. Incorporation of the two provides coherence of information across all ecosystem domains (extent, condition, services and asset values) and can be unpacked to examine potential effects of changes in each domain.

The ecosystem services estimated within the Gunbower, Koondrook and Perricoota (GKP) ecosystems (the ecosystem accounting area - EAA) fall into three broad categories: provisioning services, regulating and maintenance services and cultural services. The services to be estimated were selected and agreed on by the LEAP Team during the inception workshop. The provisioning ecosystem services assessed included biomass for native timber, biomass for firewood and floral resources for honey. Regulating and maintenance services assessed included global climate regulation (via carbon sequestration and retention) and floral resources for hive building. The cultural services considered are spiritual, artistic and symbolic services (via cultural heritage connection) and recreation-related services.

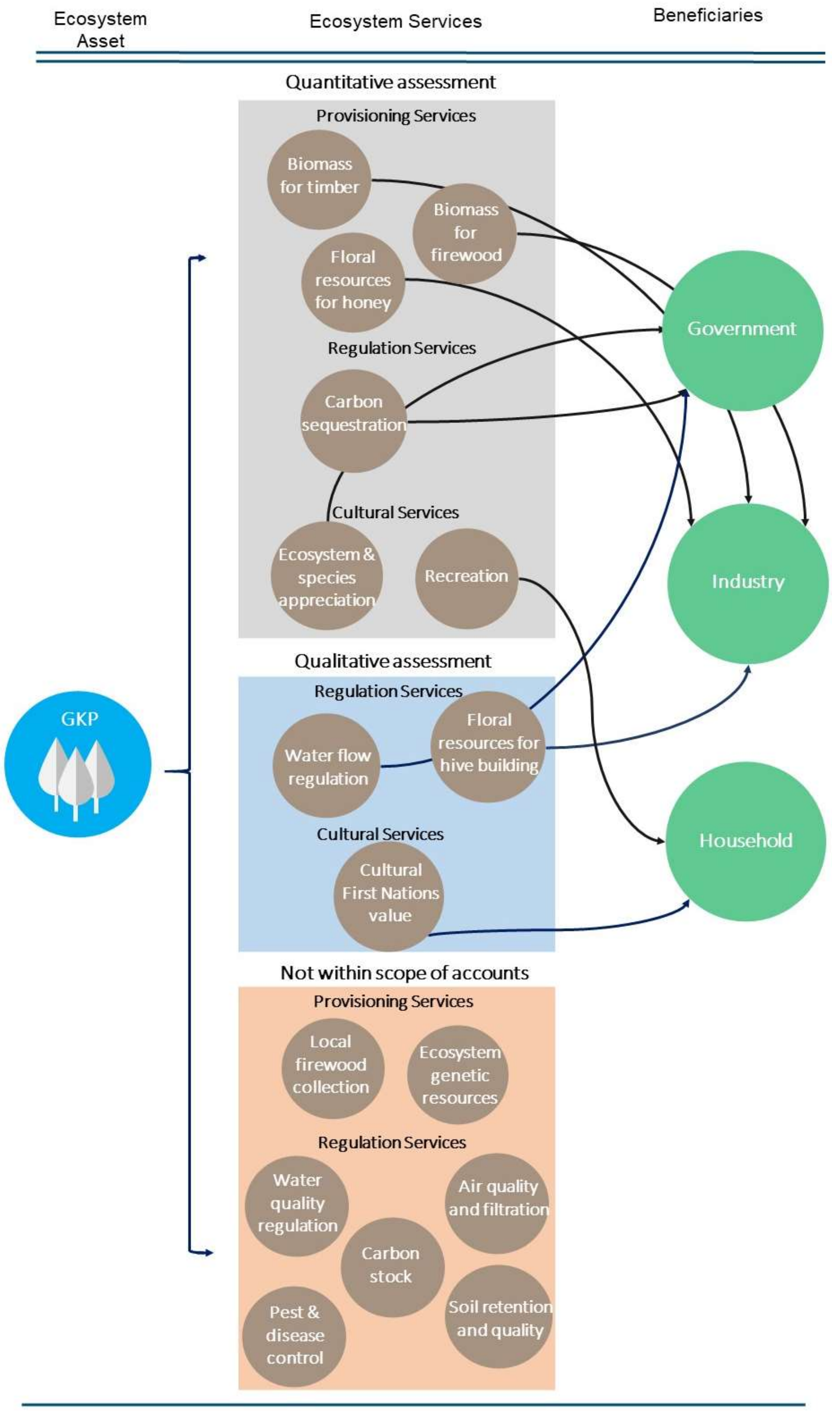
Where data is available, and benefits can be quantified within the SEEA EA accounting framework, each ecosystem service will contribute to a benefit. In some cases, the benefits are goods and services already recorded as monetary transactions, e.g. sales of timber and honey. In other cases, the benefits concerning improvements in, for example, health, are not recorded as monetary transactions. In all cases ecosystem services accounting focuses on recording the flows of ecosystem services but, as relevant, data on the related benefits is also presented.

Use of ecosystem services may be competing (for example, use of timber provisioning services will compete with global climate regulation services) or may be complementary (for example, floral resources for honey and recreation services). Ecosystem accounting allows these relationships to be recorded consistently. The use of ecosystem services may be a potential pressure on the ecosystems within GKP. Possible pressures include logging for timber and firewood supply, pollution from recreational vehicles (for example fishing boats) and people inadvertently damaging ecosystems while recreating. Throughout this section there is information on intensity of use, which may be used to assess the potential environmental and economic sustainability of different uses.

Ecosystems may also have negative effects on people (for example pests may reduce the recreational experience of campers), these are generally reflected in reduced ecosystem service flows.

Where services are quantified, they are measured in terms of physical and monetary flows (for example in kgs and dollars, respectively). Estimates in monetary terms are based on either use or non-use of exchange values as defined in the SEEA EA. Complementary monetary measures using welfare values (i.e. including consumer surplus) have been included for carbon sequestration. Physical and monetary flows are not calculated for all services. In particular, a qualitative description of the cultural significance of the Gunbower Island ecosystems to members of the Barapa Barapa and Yorta Yorta language groups is included in-lieu of accounting entries (p. 110). Also, calculation of the monetary supply and use for carbon sequestration are included, but not carbon retention. This is explained in detail in the carbon sequestration and stocks section of this paper. Figure 5 summarises which ecosystem services are and are not included in the analysis and how they connect to different beneficiaries.

Figure 5 Beneficiaries diagram



Note: Ecosystem and species appreciation services are a non-use value. All other services assessed quantitatively involve use values. See Table 4 for more details.

The results of the ecosystem services section are summarised in each individual section of this report. For each service there is a unit of measure, a quantity, a user, a time period and an ecosystem type that the quantity relates to. The relationship between beneficiaries and the environment can be characterised as comprising of both use and non-use values. Use values arise where the benefit to people is revealed through their direct, personal interaction (e.g., harvesting food, hiking in forests, benefitting from cleaner air), or through indirect use (e.g., regulation of water flows providing flood mitigation) of the environment. Use values are the focus of measurement within the SEEA EA. Non-use values are those values that people assign to ecosystems (including associated biodiversity), irrespective of whether they use (directly or indirectly), or intend to use, the ecosystems. The existence of biodiversity and the desire for its ongoing preservation is also connected to non-use values that people hold with respect to the environment (UNCEEA, 2021).

Use and non-use values can be measured using exchange and welfare values. Exchange values value ecosystem services and assets at the prices at which they are exchanged, or would be exchanged if markets were present. Exchange values satisfy the requirements of the SEEA-EEA accounting framework because the approach supports comparison of ecosystem accounting monetary values with those recorded in conventional economic and financial accounts. However, EEA recognises that the exchange valuation approach applied in ecosystem accounting does not provide a comprehensive measure of the value of nature (In particular, the monetary values captured in the SEEA framework likely reflect a sub-set of all ecosystem services and exclude measures of consumer surplus that may be of analytical interest in many contexts.

To gain a more holistic understanding of consumer surplus, welfare values are presented alongside exchange values in this report. Welfare values are economic values that reflect the economic wellbeing consumers receive from ecosystem assets. The welfare derived from a good or service is equal to the total willingness-to-pay (WTP) for it, which includes the payment made (in or outside of market transactions) and the consumer surplus. Welfare values sit outside the SEEA-EA compliant environmental economic accounts but are presented to further inform policy decisions. Where welfare values are presented, they are clearly identified and should be considered independent to the exchange values. Welfare values and exchange values are not additive and care should be taken to avoid double counting. Table 4 summarises how the monetary values for each ecosystem service in this report is presented. Note that Carbon sequestration services are presented in terms of both exchange and welfare values and that ecosystem and species appreciation is a non-use value. The non-use value of ecosystem and species appreciation concerns the wellbeing that people derive from the existence and preservation of the environment for current and future generations, irrespective of any direct or indirect use.

Care is required when relying on accounting outputs for decision making. Both the information and its accuracy vary across ecosystem services in terms of spatial and temporal coverage. Several techniques have been used to estimate the quantity of ecosystem services. Each have their own limitations, and, in most instances, additional data collection would improve the results. More information on the results and caveats are provided throughout this report.

Table 4 Ecosystem service valuation method summary

Ecosystem service	Exchange value		Welfare value		Use or non-use value	Valuation Method	Level of ecosystem data
	Presented	Table reference	Presented	Table reference			(type/state/expression)
Biomass for timber	Yes	Table 12	Yes	As exchange	Use value	Residual rents	Expression
Biomass for firewood	Yes	Table 18	-	-	Use value	Residual rents	Expression
Floral resources for honey	Yes	Table 20	Yes	As exchange	Use value	Residual rents	Type
Carbon Sequestration and Stock	Yes	Table 36 Table 37	Yes	Table 38	Use value	Exchange value	Expression
Floral resources for hive building	-	-	-	-	Use value	-	-
Ecosystem and species appreciation	Yes	Table 47	-	-	Non-use value	Exchange value	Expression
Water flow regulation	-	Table 49	-	-	Use value	Exchange value	-
Ecosystem services and First Nations	-	-	-	-	Use and non-use value	-	-
Recreation	Yes	Table 67	Yes	In text	Use value	Consumption Expenditure	-

Note: '–' means the valuation method was not included in this analysis

4.2 Wood provisioning services - Biomass for Timber

The GKP ecosystems provide biomass for commercial timber as a wood provisioning service. This service is quantified as the volume and quality of timber harvested from the Gunbower, Perricoota and Koondrook forests. The direct users of this ecosystem service are the NSW and Victorian state forestry departments, which benefit from any improvement in the degree of ecological integrity of the forest that increases quality or quantity of their sawlog yields. Figure 6 shows the relationship between the ecosystem service and these users, based on the logic chains established for ecosystem services under the SEEA EA (UN CEEA 2021).

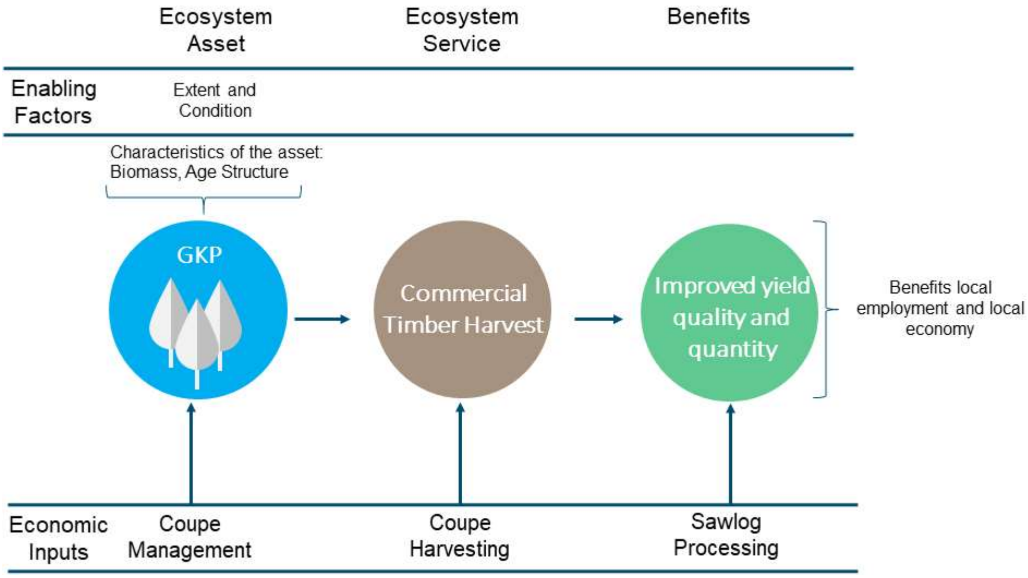
The main flow of interest in this context is the relationship between the GKP ecosystem and harvesters. The GKP ecosystem provides wood biomass for timber. Access rights to use this biomass are allocated by the government (in the form of quotas and licenses) which are reflected in the ecosystem services step as 'coupe harvesting' (Figure 6). In the GKP, ecosystem harvesting is completed by the Forestry Corp of NSW (FCNSW) and Vic Forests (VF). The quantity and quality of timber yield is a function of GKP ecosystem type and forest condition. The ecosystem type providing the service is inland eucalypt forests and woodlands.

There are other relationships that are not captured explicitly in Figure 6 but are important to consider in forest management. These include that not all biomass is allocated by government for harvest by FCNSW and VF. Trees that are not allocated for harvest remain in the forest ecosystem and can benefit other species or contribute to user experience (for example, camping). The link between the ecosystem (quantity and quality), the biomass (quantity and quality), and the transactions are key components of the narrative.

A complete information set will capture each activity or transaction, estimate the value of those transactions, and link them to an ecosystem asset to understand how the attributes and condition of the ecosystem affects the transaction. Government can contribute to the set of information outlined in Figure 6 to support the ongoing management of the GKP ecosystem.

An overview of timber harvesting areas in Gunbower and Koondrook-Perricoota is provided in Table 11 and Table 12.

Figure 6 Biomass for timber services



4.2.1 Literature review

Methods for calculating monetary supply and use for biomass for timber are well established for exchange and welfare values. A range of methods have been used in contemporary calculations of monetary supply and use for biomass for timber based on exchange values. Not all exchange value calculations are consistent with the residual rents approach outlined in Figure 3. A collection of the approaches taken to analyse the value of timber production in Australia is outlined below:

- DELWP, Victorian Forests (2019): Estimated gross operating surplus as a proxy for residual rents (The State of Victoria Department of Environment Land Water and Planning, 2019)
- IDEEA, Forico (2018): Used a residual rents approach to estimate the value of timber supply (IDEEA Group, 2018)
- ANU, Central Highlands (2016): Used a residual rents approach to estimate the value of timber supply (Keith et al., 2016)
- CSIRO, Green Triangle (2020): did not measure the exchange value of timber production (Stewart et al., 2020)
- NCEconomics, Environmental Watering Victoria (2020): did not measure the exchange value of timber production (NCEconomics, 2020)

Welfare values could diverge from exchange values where market exchange values do not price in premiums that customers are willing to pay for native timber. We do not propose estimating a separate welfare value for commercial timber because the exchange and welfare values will be similar. The exchange and welfare values calculated for the commercial timber industry are likely to converge, assuming an efficient and competitive market hypothesis. The exchange value of commercial timber is output price, less input costs and depreciation. This sets the exchange value on the competitive market and is the method we are using to calculate the value of commercial timber within this analysis. There is a chance that consumers assign a premium to native timber sourced from the GKP ecosystem and are willing to pay more for it in a competitive market. For example, some literature shows that timber users are willing to pay premiums (rents) above the efficient market price for certified timber (Aguilar & Vlosky, 2007). To the extent that this type of premium is not already captured in exchange values, welfare values will diverge from exchange values. Our view is that the premium here is likely to be negligible however, this premium should in principle be captured in efficient market prices.

4.2.2 Method

Physical and monetary ecosystem service accounts for 2010 and 2015 were produced in this analysis. A particular focus of this analysis was to integrate the account ready data on extent and condition summarised in the GKP Experimental Accounts Report (McLeod et al., 2021) with more details provided in technical reports on extent and condition (Mokany et al., 2021; Richards AE et al., 2021b; Richards AE et al., 2021a; Richards AE et al., 2021c).

Detailed methods for physical and monetary ecosystem service accounts are outlined below. All datasets relied on for the analysis of ecosystem services are referenced at the bottom of the account tables.

Physical ecosystem service accounts – biomass for timber

Method

Spatial data for timber harvesting was sourced from open access datasets from DataVic (Department of Jobs, Precincts and Jobs, Forestry and Game Branch) and Forestry Corporation of NSW. Data for Gunbower and Koondrook Perricoota forests captured historical harvesting areas from recent decades until previous financial year. Publicly available Forestry Corporation data is more comprehensive identifying management exclusion zones (waterways, wetlands and high value vegetation) for each forest compartment. Harvest plans or timber release plans were not available for the sites.

Timber harvest data was provided by Forestry Corporation (annual volume and mass yields and timber grades) and VicForest (volume yield estimates per hectare for sawlog and firewood) which were the same for 2010 and 2015. All timber harvest data was attributed to Inland floodplain eucalypt forests and woodlands ecosystem type.

Gunbower timber harvest data used in the accounts are estimates only as timber was identified as sawlogs without grades. Tonnage estimates used in the accounts was based on converting estimated volumes to tonnes using a multiplication factor of 1.3 (volume x 1.3 = tonnes). This conversion factor was based on volume to mass ratios provided in Forestry corporation yield data. Forestry Corporation provided Koondrook Perricoota sawlog grades indicating a variable harvest of sawlog quality in 2010 and 2015 (Table 5). Overall harvest was significantly greater in 2010 than 2015. The provision of native timber (tonnes and volumes) to the timber industry from the GKP was then quantified.

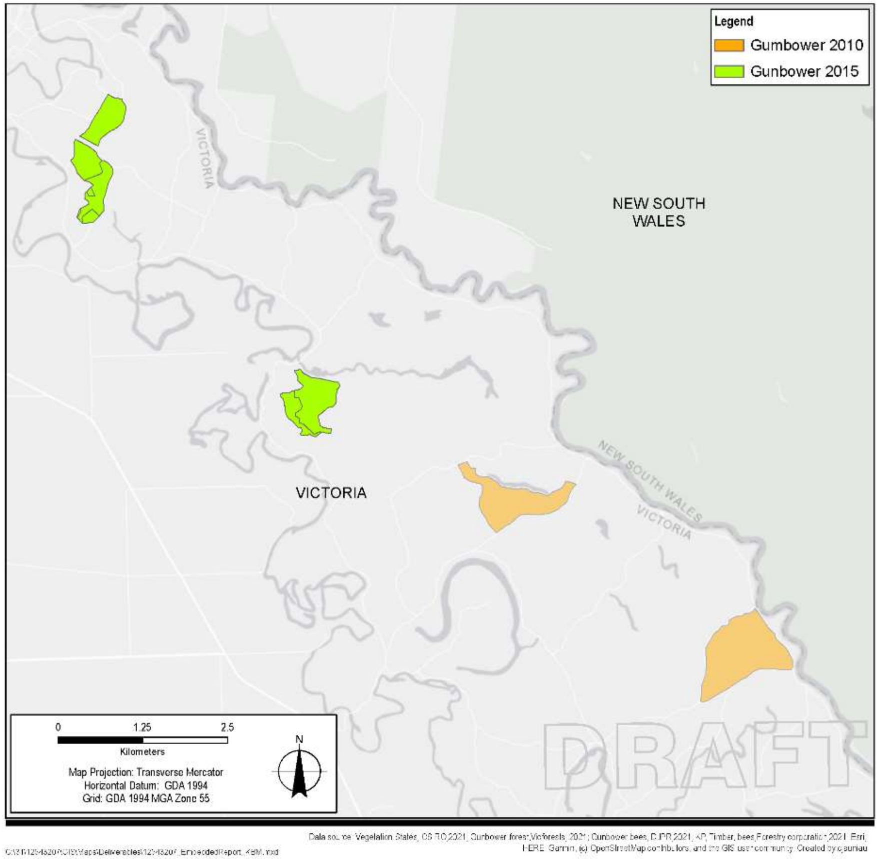


Figure 7 Timber and firewood harvesting areas Gunbower forest

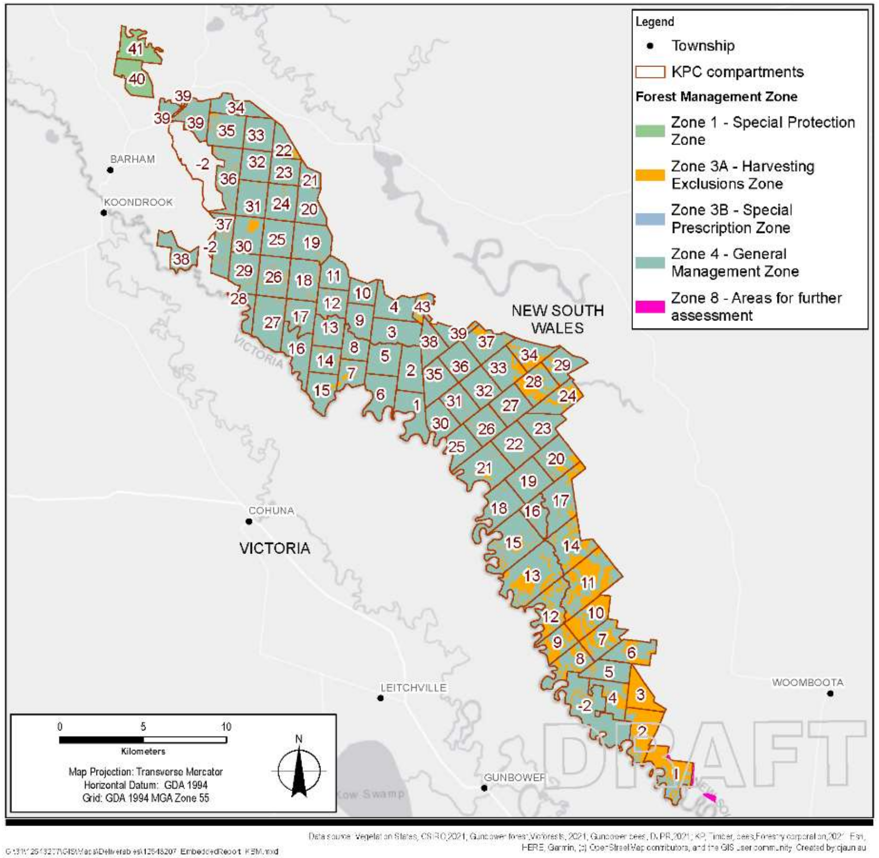


Figure 8 Timber and firewood harvesting compartments in Koondrook Perricoota

Estimates

Estimates used to generate the accounting outputs in Table 11 are summarised below.

Table 5 Summary of sawlog grades harvested from Koondrook Perricoota in 2010 and 2015 from locations provided in Table 11 and Table 12.

Timber type	Sum of 2010 tonnes	Sum of 2015 tonnes
Large Sawlog	0	170.48
Miscellaneous Grade 1		8.62
Salvage Grade 1	33579.25	8416.15
Salvage Grade 2	1212.8	
Sawlog	12234.84	
Small Sawlog	0	0
Grand Total	**47026.89**	**8595.25**

Areas harvested in Gunbower and Koondrook-Perricoota in 2010 and 2015 are from spatially separate coupes with no additional harvest between 2011 and 2014 this reduces additional managed losses from logging the same compartments in consecutive years.

Monetary ecosystem service accounts – biomass for timber

Method

The monetary ecosystem accounts for biomass for timber calculate the exchange value of the ecosystem services determined under the physical ecosystem accounts. The ecosystem service of biomass for timber can be valued by applying a residual rent dollar value to each tonne of timber yield in 2010 and 2015 respectively. This relationship is represented by:

$$\$ES_{ti,y,i,t,e} = Ti_{y,i,t,z} * RR_{y,i,t}$$

Where:

- $\$ES_{ti,y,i,t,e}$ is the value of the timber harvest (ti), in year (y), at geographic location (i), ecosystem type (t), measured as an exchange value (e)
- $Ti_{y,i,t,z}$ is the timber yield (tonnes) in year (y), from geographic location (i), ecosystem type (t), for quality (z)
- $RR_{y,i,t}$ is the per unit (tonne) residual rent from harvested timber in year (y) from location (i), ecosystem type (t).

A general description of how monetary ecosystem accounts for biomass for timber were produced is outlined below:

The biomass for timber supplied to government was interrogated. This is summarised in Table 6 below.

Table 6 Biomass for timber physical supply 2010 and 2015

			Ecosystem Type	
			Inland floodplain eucalypt forests and woodlands	
Biomass for Timber	Year	Unit	Gunbower	Koondrook-Perricoota
Supply	2010	Tonnes	962	47,026
Supply	2015	Tonnes	432	8,595

The residual rents approach is used to value the supply of biomass for timber. Residual rent of timber harvesting is estimated as the royalty value (stumpage value) of timber for sawlogs in the GKP ecosystem less depreciation costs. This represents the residual economic value that the harvester of the sawlog gains after all costs of extraction (transport of timber to mill door) or use (mill processing) and normal returns from production have been considered. Importantly, resource rent is not the revenue from the sales, nor the gross operating surplus. These types of values will overstate the residual rent attributable to the biomass for timber. The exchange based residual rents approach is covered in detail below.

Different methods were used to calculate the biomass for timber exchange value in Koondrook-Perricoota and Gunbower Forest. This was a result of access to the necessary data. NSW Forestry Corp provided detailed yield information on timber yield and quality from Koondrook-Perricoota in 2010 and 2015 (Table 7). Table 7 presents the tonnes and m3 of yield from Koondrook-Perricoota forest, which allowed calculation of the residual rents associated with yield in Koondrook-Perricoota based on stumpage price per m3 of each standard of timber.

Table 7 Koondrook-Perricoota biomass for timber physical supply

	2010		2015	
Koondrook-Perricoota Yield	tonnes	m3	tonnes	m3
Large Sawlog	-	2,678	170	4,215
Small Sawlog	-	2	-	2
Sawlog	12,235	5,250	-	-
Salvage Grade 1	33,579	12,966	8,416	6,405
Salvage Grade 2	1,213	916	-	-
Miscellaneous Grade 1	-	-	9	12
Total	47,027	21,812	8,595	10,633

The residual rents per unit of biomass for timber supply are multiplied by the physical supply units to determine the exchange value.

Stumpage price in NSW relied on analysis by the NSW Department of Primary Industries (NSW DPI) in 2017 (Industries, 2017). NSW DPI engaged GHD to undertake a review of Coastal

Hardwood Supply across the state. Average stumpage price, otherwise referred to as the royalty from the timber value, was recorded for High Quality (HQ) and Low Quality (LQ) Sawlogs as well as Pulpwood on the South Coast, North Coast and Eden.

Table 8 Stumpage Price in NSW (Average of South Coast, North Coast and Eden)

	Stumpage Price ($/m3)	
Yield Quality	2010	2015
HQ Sawlog	77	71
LQ Sawlog	14	15
Pulpwood	12	10

Table 9 demonstrates how the average NSW stumpage prices (Table 8) were applied to the different quality of biomass for timber supplied by Koondrook-Perricoota forest. Average stumpage price across NSW for HQ sawlogs was applied to KP yield Large sawlog, small sawlog and sawlog category. LW Sawlog Stumpage price was applied to Salvage grade 1 and salvage grade 2 yield. Miscellaneous grade 1 was applied the lowest stumpage value reserved for pulpwood. Stumpage value is the product of timber yield (m3) for each sawlog quality and the stumpage price applied to that quality (Table 9).

Table 9 Stumpage Prices applied to Koondrook-Perricoota Forest Supply

Koondrook-Perricoota Yield quality	Stumpage Price Applied ($/m3)		Timber yield (m3)		Total Stumpage Value	
	2010	2015	2010	2015	2010	2015
Large Sawlog	77	71	2,678	4,215	205,294	299,232
Small Sawlog	77	71	2	2	162	109
Sawlog	77	71	5,250	-	402,513	-
Salvage Grade 1	14	15	12,966	6,405	181,529	93,946
Salvage Grade 2	14	15	916	-	12,819	-
Miscellaneous Grade 1	12	10	-	12	-	112
Total (rounded)			21,812	10,633	802,300	393,400

Note: Stumpage price applied were sourced from NSW DPI report. Confidence in data is moderate as they are averages across alternate NSW regions. Yield values from Koondrook-Perricoota forest were provided by NSW Forestry Corp. Confidence in data is high.

Source: NSW Forestry Corp, NSW DPI

In comparison, Vic Forests provided average tonnes per hectare of timber harvested in 2010 and 2015. The grade of the biomass for timber supplied by the Gunbower Forest was not specified and an average stumpage price (royalty value) of $69 per tonne of sawlogs harvested in 2010 and 2015 was provided (Table 6). The stumpage value is the product of the stumpage price ($/tonne) and timber yield (tonnes) supplied by Gunbower Forest in 2010 and 2015 (Table 10).

Table 10 Stumpage Prices applied to Gunbower Forest Supply

	Stumpage Price Applied ($/tonne)		Timber yield (tonne)		Total Stumpage Value	
Gunbower Yield	2010	2015	2010	2015	2010	2015
Sawlog	69	69	962	432	66,378	29,808
Total (rounded)					66,400	29,800

Note: Stumpage price applied was provided by Vic Forests. Confidence in data is moderate as they are averages. Yield values from Gunbower forest include some uncertainty and are averages across the thinned region (Ha). Estimates can be improved with finer scale collection of timber yield and related variable and fixed cost data.

Source: Vic Forests

Estimates

The total stumpage values calculated in Table 9 and Table 10 encapsulate the value of biomass for timber supplied by the GKP ecosystem. The total stumpage values are equivalent to the monetary supply of biomass for timber across the relevant GKP ecosystem types in the accounting outputs in Table 12.

4.2.3 Areas for improvement

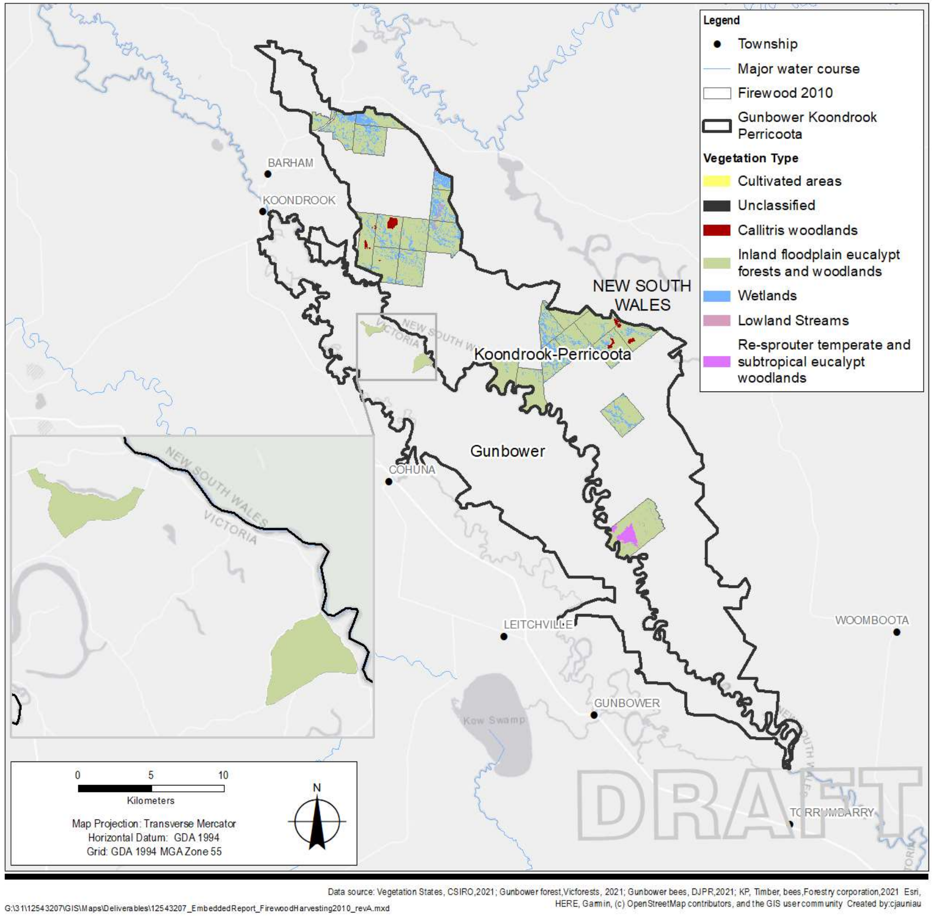
Additional research should focus on improving the central collection and open access to ecosystem supply data. This analysis collated information on the biomass for timber provided by the GKP ecosystem from several different sources with varying levels of difficulty. Data resourcing for use in ecosystem accounting should be organised to assist future calculations. Data sources were variable in relation to detailed site information such as harvest plans, predicted yields and coupe logging volumes and tonnage. Biomass for timber supply data should be supplemented with detailed records of use data: the costs of harvest and transport and the stumpage value compared to the mill door value of sawlog timber yielded. This approach will streamline the calculation of residual rents of ecosystem supply to ensure account accuracy. This will provide managers with an improved understanding of what the ecosystem is providing to different stakeholders and substantially improve their ability to make management decisions.

4.2.4 Accounting outputs

A biomass for timber physical supply and use table (Table 11) and monetary supply and use table (Table 12) were developed for the ecosystem accounting area. Supply and use tables show the relationship between biomass for timber supplied in 2010 and 2015, the GKP ecosystem, with the forestry industry as the user. This approach aligns with the SEEA framework (UNCEEA, 2021a).

The physical supply and use table (Table 11) illustrates tonnes of biomass for timber harvested from Gunbower forest and Koondrook Perricoota forest in 2010 and 2015. A minimum of 962 tonnes and 432 tonnes of biomass for timber were harvested from Gunbower forest in 2010 and 2015 respectively. 4,809 tonnes were harvested from Koondrook Perricoota forest in 2010 and 8,595 tonnes in 2015. 47,988 total tonnes of biomass for timber were harvested across the GKP ecosystem in 2010, this dropped to 9,027 tonnes of total yield in 2015. Biomass for timber was only harvested from the inland floodplain eucalypt forests and woodlands and use is allocated to the forestry industry.

The monetary supply and use table (Table 12) outlines the residual rents associated with the biomass for timber harvested in 2010 and 2015. The 432 tonnes harvested from Gunbower forest and 8,595 tonnes from Koondrook-Perricoota in 2015 have a residual rent of $30,000 and $393,000 respectively. This equates to a total monetary supply of around $423,200. This is the total value of the timber, less the costs of harvest and depreciation. Timber harvested in 2010 had a total monetary supply of around $868,000, $66,000 of that total was supplied by the Gunbower forests and $802,000 by the Koondrook-Perricoota forest.



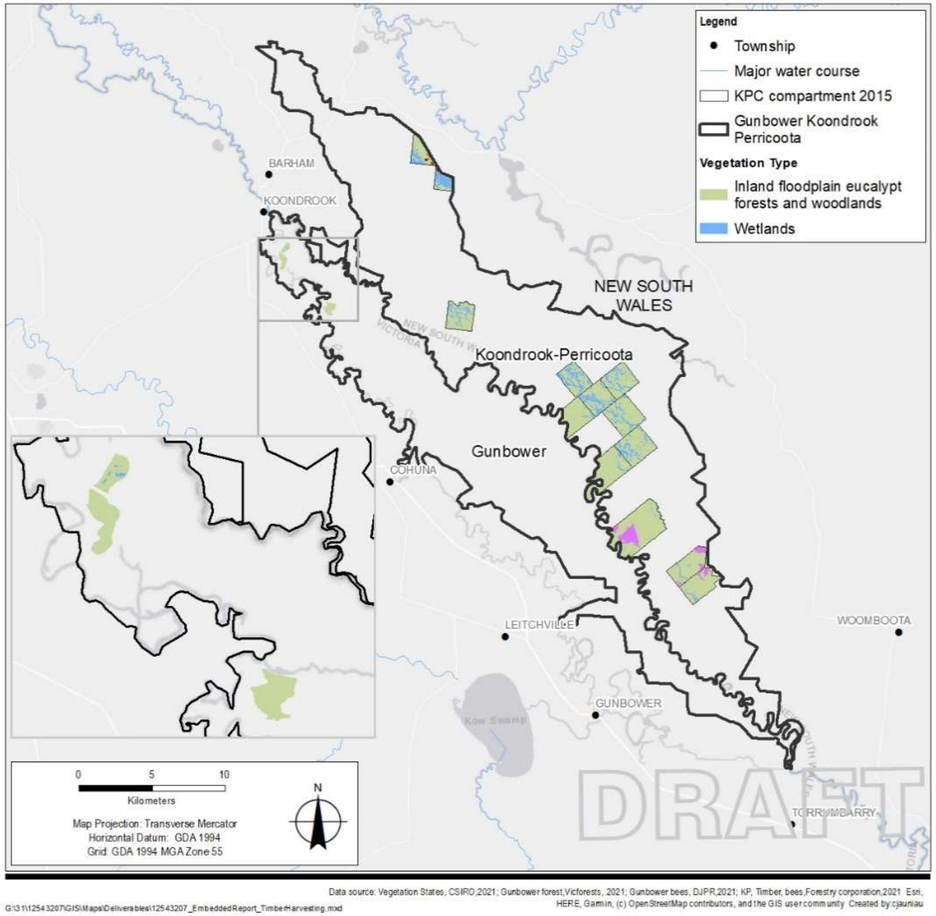


Figure 9 GKP timber harvesting compartments accessed in 2010 and ecosystem type within each compartment.

Figure 10 GKP timber harvesting compartments accessed in 2015 and ecosystem type within each compartment.

Table 11 Biomass for timber physical supply and use table, GKP, 2010 and 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply /Use	Units	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
2010																
Supply	tonnes				-	962	-	-	-	-	-	47,026	-		-	-
Use	tonnes			47,988												
2015																
Supply	tonnes				-	432	-	-	-		-	8,595	-		-	-
Use	tonnes			9,027												

Note: Supply and use of biomass for timber is derived from 2010 and 2015 yields. Yields data was measured in tonnes and m3 across specific coupes (Ha). Confidence in data is high. Sawlog yield data from NSW Forest Corp was defined by sawlog quantity and quality across different harvesting areas in Koondrook and Perricoota forests. Yield data from Victorian Department of Jobs, Precincts and Regions was averaged and contains some uncertainty. Estimates can be improved with finer scale collection of timber yield data within the harvested coupes that identifies go and no go areas, especially within NSW forestry coupes. '–' = 0

Source: Data from (Victorian Department of Jobs, Precincts and Regions, 2021 and NSW Forest Corp, 2021)

Table 12 Biomass for timber monetary supply and use summary table, GKP, 2010 and 2015

		Economic units			Ecosystem type											
					Gunbower					Koondrook - Perricoota						
Supply/Use	Units	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
2010																
Supply	$ AUD				-	66,000	-	-	-	-	-	802,000	-	-	-	-
Use	$ AUD			868,000												
2015																
Supply	$ AUD				-	30,000	-	-	-	-	-	393,000	-	-	-	-
Use	$ AUD			423,000												

Note: Residual rents of biomass for timber are derived from 2010 and 2015 royalty estimates and are presented in nominal terms. Residual rents are the total monetary output less the costs of timber harvest and depreciation. Confidence in estimates is high. Sawlog royalties have been adjusted based on evidence from Victorian Department of Jobs, Precincts and Regions and New South Wales Department of Primary Industries. Yield values from Gunbower forest include some uncertainty and are averages across the thinned region (Ha). Estimates can be improved with finer scale collection of timber yield and related variable and fixed cost data. '–' = 0

Source: Data from (Victorian Department of Jobs, Precincts and Regions, 2021 and NSW Department of Primary Industries, 2017)

4.3 Wood provisioning service - Biomass for Firewood

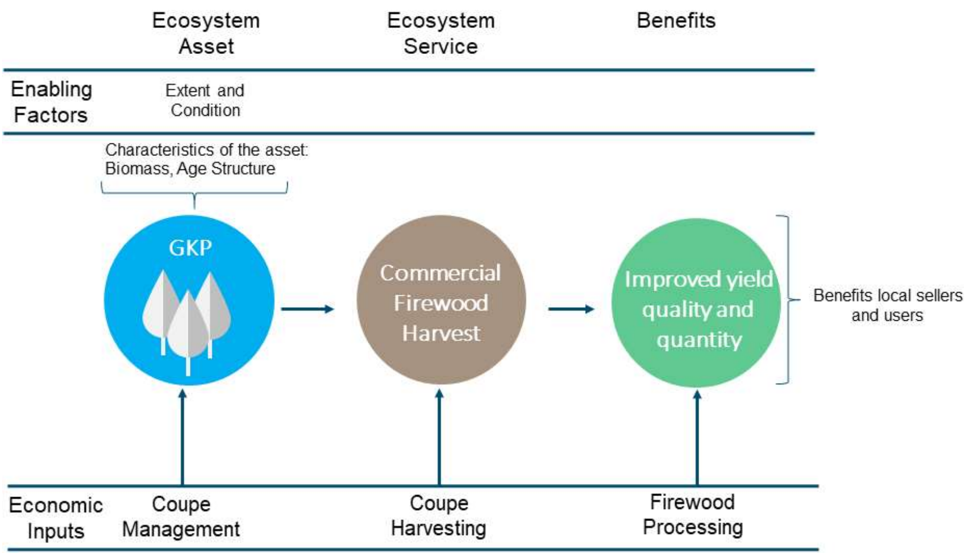
The GKP ecosystem provides biomass for commercial firewood as a wood provisioning service in the same way that it provides biomass for commercial timber. Provision of biomass for commercial firewood is quantified as the volume and quality of firewood harvested from the Gunbower, Koondrook and Perricoota forests in the target years for commercial sale. The direct user of this ecosystem service is the local timber industry, which benefits from any improvement in the ecological integrity of the forest that increases quality or quantity of their firewood yields. Figure 11 shows the relationship between the ecosystem service and users. It is important to note that collection of firewood by households within the GKP is not included in this analysis. Biomass for firewood collected by households is understood to be an important service that the GKP provides but was out of scope of this analysis as sufficient data was not accessible.

The main flow of interest in this context is the relationship between the GKP ecosystem and users. The government allocates access rights to the use of the wood biomass (in the form of quotas and licenses) which are reflected in the ecosystem services step as 'coupe harvesting' (Figure 11). Forestry Corp of NSW (FCNSW) and Vic Forests (VF) complete firewood harvesting in the GKP ecosystem in the same way they complete sawlog harvesting. The quantity and quality of firewood yield is a function of GKP ecosystem type and forest condition. The ecosystem type providing the service is inland eucalypt forests and woodlands.

There are other relationships that are not captured explicitly in Figure 11 but are important to consider in forest management. The biomass is allocated by government for harvest by FCNSW and VF. Trees that are not harvested remain within the forest ecosystem to benefit other species or contribute to user experience (for example, camping). The link between the ecosystem (quantity and quality), the biomass (quantity and quality), and the transactions are key components of the narrative.

A complete information set will capture each activity or transaction, estimate the value of those transactions, and link them to an ecosystem asset to understand how the attributes and condition of the ecosystem affects the transaction. Government can contribute to the set of information outlined in Figure 11 to support the ongoing management of the GKP ecosystem.

Figure 11 Biomass for firewood services



4.3.1 Literature review

Methods for calculating monetary supply and use for biomass for firewood are well established for exchange and welfare values. A range of methods have been used in contemporary calculations of monetary supply and use for biomass for firewood based on exchange values. Not all exchange value calculations are consistent with the residual rents approach outlined in Figure 3. A collection of the approaches taken to analyse the value of firewood production in Australia is outlined below:

- DELWP, Victorian Forests (2019): estimated gross operating surplus as a proxy for residual rents (The State of Victoria Department of Environment Land Water and Planning, 2019)
- IDEEA, Forico (2018): Used a residual rents approach to estimate the value of firewood supply (IDEEA Group, 2018)
- NCEconomics, Environmental Watering Victoria (2020): did not measure the exchange value of firewood production (NCEconomics, 2020)
- CSIRO, Green Triangle (2020): did not measure the exchange value of firewood production (Stewart et al., 2020)
- ANU, Central Highlands (2016): did not measure the exchange value of firewood production (Keith et al., 2016)

4.3.2 Method

Physical and monetary ecosystem service accounts were produced for biomass for firewood. As with the biomass for timber accounts, a particular focus of the ecosystem service accounts was to integrate the account ready extent and condition data outlined in the previous chapters. A summary of the method for the physical and monetary supply and use is provided below. Detailed methods for both ecosystem service accounts are outlined below. All datasets relied on for the analysis of ecosystem services are referenced at the bottom of the account tables.

Physical ecosystem service accounts – biomass for firewood

Method

The physical ecosystem accounts for biomass for firewood calculate the supply of each of the ecosystem services. The estimation of physical ecosystem service accounts for biomass for firewood is as follows:

Spatial data for firewood harvesting locations was sourced from open access datasets from DataVic (Department of Jobs, Precincts and Jobs, Forestry and Game Branch) and Forestry Corporation of NSW. Data for Gunbower and Koondrook Perricoota forests captured historical harvesting areas from recent decades until previous financial year. Publicly available Forestry Corporation data identifies management exclusion zones (waterways, wetlands and high value vegetation) for each forest compartment. Harvest plans or timber release plans were not available for the sites.

Firewood harvest data was provided by Forestry Corporation (annual volume and mass yields for firewood) and VicForest (volume yield estimates per hectare for firewood). All firewood harvest data was attributed to the ecosystem characteristic of Inland floodplain eucalypt forests and woodlands ecosystem type.

Gunbower firewood harvest data used in the accounts are estimates only as data was provided as volumes per Ha. Mass estimates used in the accounts was based on converting estimated volumes to tonnes using a multiplication factor of 1.3 (volume x 1.3 = tonnes). This conversion factor was based on volume to mass ratios provided in Forestry Corporation yield data.

Based on an analysis of the data provision of native firewood timber (tonnes) to the timber industry from the GKP was quantified.

Estimates

Estimates used to generate the accounting outputs in Table 11 are summarised below.

Areas harvested in Gunbower in 2010 and 2015 are from spatially separate coupes with no harvest occurring from 2011 to 2014. Area harvested in Koondrook Perricoota include compartments where firewood harvesting has occurred during the intervening years (Figure 12). It is anticipated timber harvesting has been progressively implemented in these areas as part of overall harvest plans. Harvest plans details for coupes and time periods were not available to further assess these localities. This information would assist the assessment of overall anticipated yield and a way to assess capacity of the system.

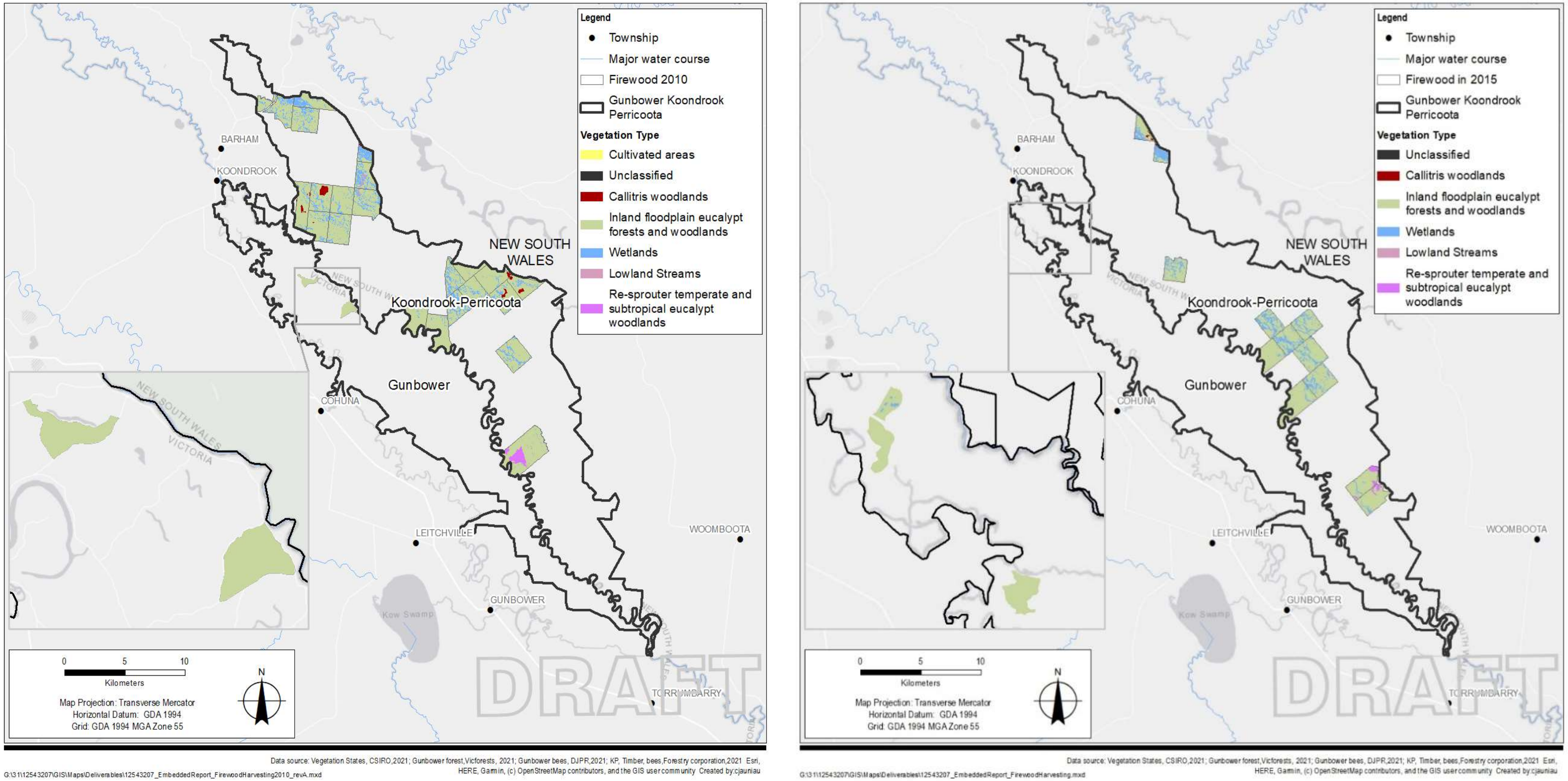


Figure 12 Firewood harvesting areas in 2010 and 2015 across GKP with ecosystem type defined in each harvest area.

Table 13 Summary of firewood timber harvest from coupes assessed in 2010 and 2015. Data indicates firewood was also harvested from these compartments between 2011 and 2014. (not all timber compartments accessed are shown)

	2010	2011	2012	2013	2014	2015
Timber compartment	Tonnes per annum firewood harvested					
13	818.74					5834.24
19	3597.3		25.28	3168.26	8824.22	4702.54
20	822.04	93.96				
21	211.38	93.92		14809.78	3450.19	2727.9
22	5059.6			4182.5	925.08	7169.61
23			5769.74			
24			3982.24			
25	62.23					12523.75
26	1131.56	119.1	119.01		221.18	9974
29	12181.14		8394.93	1446.92		
30	5404.33	91.34				
Total per annum	29288.32	398.32	18291.2	23607.46	13420.67	42932.04

Monetary ecosystem service accounts – biomass for firewood

Method

The monetary ecosystem accounts for biomass for firewood calculate the exchange value of the ecosystem services determined under the physical ecosystem accounts. The ecosystem provision service of biomass for firewood supply can be valued by applying a residual rent dollar value to each tonne of firewood yield in 2010 and 2015 respectively. This relationship is represented by:

$$\$ES_{f,y,i,t,e} = F_{y,i,t,z} * RR_{y,i,t}$$

Where:

$\$ES_{f,y,i,t,e}$ is the value of the firewood harvest (f), in year (y), at geographic location (i), ecosystem type (t), measured as an exchange value (e)

$F_{y,i,t,z}$ is the firewood yield (tonnes) in year (y) from geographic location (i), ecosystem type (t) for quality (z)

$RR_{y,i,t}$ is the per unit (tonnes) residual rent from firewood in year (y) from location (i), ecosystem type (t).

A general description of how monetary ecosystem accounts for biomass for firewood were produced is outlined below:

The biomass for firewood supplied to government was interrogated. This is summarised in Table 14 below.

Table 14 Biomass for firewood physical supply 2010 and 2015

			Ecosystem Type	
			Inland floodplain eucalypt forests and woodlands	
Biomass for Firewood	Year	Unit	Gunbower	Koondrook-Perricoota
Supply	2010	Tonnes	4,809	69,322
Supply	2015	Tonnes	2,162	55,775

The residual rents approach is used to value the supply of biomass for firewood. The residual rent of firewood harvest is the royalty value (stumpage value) of timber for firewood in the GKP ecosystem less depreciation costs. This represents the residual economic value that the harvester of the firewood gains after all costs of extraction (transport to mill door) or use (mill processing) and normal returns from production have been considered. Importantly, resource rent is not the revenue from the sales exchange, nor the gross operating surplus. These values will overstate the residual rent attributable to the biomass for firewood and are not directly comparable to the methods and valuations for GKP as a result. The exchange based residual rents approach is covered in detail below.

The biomass for firewood exchange value in Koondrook-Perricoota and Gunbower Forest was calculated in the same way.

The residual rents per unit of biomass for firewood supply is multiplied by the physical supply units (Table 14) to determine the total stumpage value. Vic Forests advised that the average stumpage price for firewood in Gunbower forest was $20/tonne. This stumpage price was also applied to physical supply from Koondrook-Perricoota forest in the absence of region-specific data.

Table 15 Stumpage Prices applied to Gunbower Forest Supply

	Stumpage Price Applied ($/tonne)		Firewood yield (tonne)		Total Stumpage Value	
Gunbower Yield	2010	2015	2010	2015	2010	2015
Firewood	20	20	4,809	2,162	96,180	43,240
Total (rounded)					96,200	43,200

Note: Stumpage price applied was provided by Vic Forests. Confidence in data is moderate as it is an average. Yield values from Gunbower forest include some uncertainty and are averages across the thinned region (Ha). Estimates can be improved with finer scale collection of firewood yield and related variable and fixed cost data.

Source: Vic Forests

Table 16 Stumpage Prices applied to Koondrook-Perricoota Forest Supply

Koondrook-Perricoota Yield	Stumpage Price Applied ($/tonne)		Firewood yield (tonne)		Total Stumpage Value	
	2010	2015	2010	2015	2010	2015
Firewood	20	20	69,322	55,775	1,386,438	1,115,500
Total (rounded)					1,386,400	1,115,500

Note: Stumpage price applied was provided by Vic Forests. Confidence in data is moderate as it is an average. Yield values from Koondrook-Perricoota forest were provided by NSW Forest Corp and are high confidence. Estimates can be improved with finer scale collection of firewood yield and related variable and fixed cost data.

Source: Vic Forests, NSW Forest Corp

Estimates

The total stumpage values calculated in Table 15 and Table 16 encapsulate the value of biomass for firewood supplied by the GKP ecosystem. The total stumpage values are equivalent to the monetary supply of biomass for firewood across the relevant GKP ecosystem types in the accounting outputs in Table 18.

4.3.3 Areas for improvement

The same areas for improvement for biomass for timber are relevant in relation to biomass for firewood supplied by the GKP ecosystem. This analysis collated information on the biomass for timber provided by state agencies with varying levels of detail. Harvest and coupe plans (2018-2019) include estimated timber quantity and quality, harvest locations, method of harvest which would significantly improve supply and use and contribute to ecosystem capacity assessments.

Data resourcing for use in ecosystem accounting should be organised to assist future calculations. Data sources were variable in relation to detailed site information such as harvest plans, predicted yields and coupe logging volumes and tonnage. Biomass for timber supply data should be supplemented with detailed records of use data: the costs of harvest and transport and the stumpage value compared to the mill door value of sawlog timber yielded. This approach will streamline the calculation of residual rents of ecosystem supply to ensure account accuracy. This would provide managers with a more complete picture of ecosystem supply and substantially improve their ability to make management decisions.

4.3.4 Accounting outputs

A biomass for firewood physical supply and use table (Figure 11) and monetary supply and use table (Figure 11) were developed for the accounting area in 2010 and 2015. Supply and use tables show the relationship between biomass for firewood supplied, the GKP ecosystem, and the government as the user.

In 2010, the physical supply and use table (Table 17) illustrates that a minimum of 4890 tonnes of biomass for firewood was harvested from Gunbower forest and 47,026 tonnes from Koondrook-Perricoota forest in 2010. The 2010 total firewood yield across GKP is 47,998 tonnes. All yield was harvested from the inland floodplain eucalypt forests and woodlands and is allocated to the local firewood industry.

The 2015, the physical supply and use table (Table 17) illustrates that a minimum of 2,162 tonnes of biomass for firewood was harvested from Gunbower forest and 55,775 tonnes from Koondrook Perricoota forest. The 2015 total yield of 57,937 tonnes was exclusively harvested from the inland floodplain eucalypt forests and woodlands ecosystem type in both forests and is allocated to the firewood industry.

The monetary supply and use table (Table 18) presents the residual rents associated with the biomass for firewood harvested in 2010 and 2015. Total biomass for firewood harvested in 2010 has a residual rent of around $1,482,000. More firewood was harvested from Koondrook Perricoota forest in 2015 than 2010, and the total residual rent of harvest from the GKP ecosystem in 2015 is around $1,159,000. These total exchange values for biomass for firewood includes the total sale value of the firewood less the costs of harvest, transport and depreciation.

Table 17 Biomass for firewood physical supply and use table, GKP, 2010 and 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply/ Use	Units	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
2010																
Supply	tonnes				-	4,809	-	-	-	-	-	69,322	-	-	-	-
Use	tonnes			74,131												
2015																
Supply	tonnes				-	2,162	-	-	-	-	-	55,775	-	-	-	-
Use	tonnes			57,937												

Note: Supply and use of biomass for firewood is derived from 2010 and 2015 yields. Yield data was measured in tonnes and m3 across specific coupes (Ha). Confidence in data is high. Firewood yield data from NSW Forest Corp was defined by tonne and m3 within different harvesting areas in Koondrook and Perricoota forests. Yield data from Victorian Department of Jobs, Precincts and Regions was averaged and contains some uncertainty. Estimates can be improved with finer scale collection of firewood yield data within the harvested coupes that identifies go and no go areas, especially within NSW forestry coupes. '–' = 0

Source: Data from Victorian Department of Jobs, Precincts and Regions, 2021 and NSW Forest Corp, 2021

Table 18 Biomass for firewood monetary supply and use summary table, GKP, 2010 and 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply/ Use	**Units**	**Household**	**Government**	**Industries**	**Fire-intolerant *Callitris* woodlands**	**Inland floodplain eucalypt forests and woodlands**	**Wetlands**	**Cultivated areas**	**Re-sprouter temperate and subtropical eucalypt**	**Lowland Streams**	**Fire-intolerant *Callitris* woodlands**	**Inland floodplain eucalypt forests and woodlands**	**Wetlands**	**Cultivated areas**	**Re-sprouter temperate and subtropical eucalypt**	**Lowland Streams**
2010																
Supply	$ AUD				-	96,000		-	-	-	-	1,386,000		-	-	-
Use	$ AUD			1,482,000												
2015																
Supply	$ AUD				-	43,000		-	-	-	-	1,116,000		-	-	-
Use	$ AUD			1,159,000												

Note: Residual rents of biomass for firewood are derived from 2010 and 2015 royalty estimates and are presented in nominal terms. Residual rents are the total monetary output less the costs of firewood harvest and depreciation. Confidence in estimates is high. Firewood royalties have been adjusted based on evidence from Victorian Department of Jobs, Precincts and Regions and New South Wales Department of Primary Industries. Yield values from Gunbower forest include some uncertainty and are averages across the thinned region (Ha). Estimates can be improved with finer scale collection of firewood yield and related variable and fixed cost data. '–' = 0

Source: Data from Victorian Department of Jobs, Precincts and Regions, 2021 and NSW Department of Primary Industries, 2017

4.4 Floral resources for Honey

The GKP ecosystem provides floral resources that support the production of Honey as a service. Honey production is based on the service provided by European Honey bees (*Apis mellifera*) introduced to Australia from Europe in 1822. This service is quantified as the volume and quality of honey from the Gunbower, Perricoota and Koondrook forests. The direct user of this ecosystem service are local Victorian and NSW apiarists who place hives in the GKP ecosystem when it flowers sufficiently. Apiarists benefit from any improvement in the condition of the forest that increases abundance or duration of flowering events and therefore increases the honey yields and health of their hives. Figure 13 shows the relationship between the ecosystem service and humans.

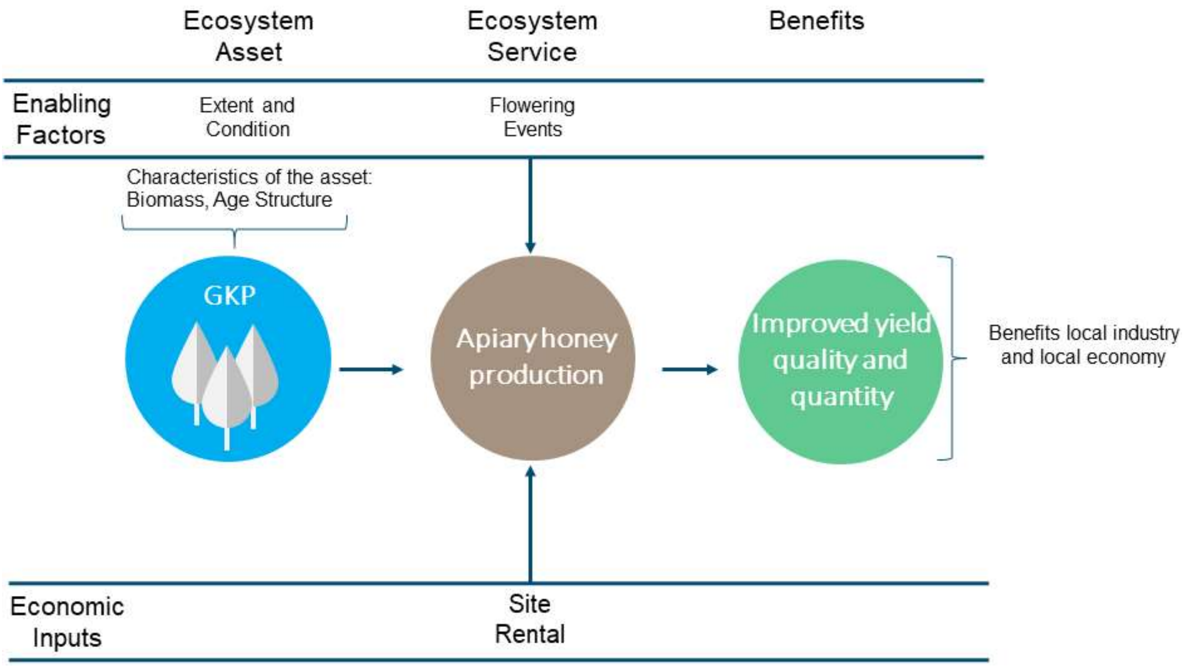
The main transaction of interest in this context is the relationship between the GKP ecosystem and apiarists. The GKP ecosystem provides floral resources for honey as a biotic asset. Access rights to use this biotic asset are allocated by the government (in the form of accessible sites to place hives) which are reflected in the ecosystem services step as 'site rental' (Figure 13).

Flowering events enable the GKP to provide honey for apiarists with access. Apiary is a migratory industry and apiarists only place their hives on sites to produce honey when the floral resources in the surrounding forest (flowering events) are sufficient. *Eucalyptus camaldulensis* (River red gum) typically have a large flowering event every two years. Consultation with local apiarists suggests that River red gums in the GKP ecosystem sustained a two-year flowering pattern up until the year 2000. Local beekeepers report that flowering events have not been as large or regular in Gunbower, Koondrook or Perricoota forests since 2000. Flowering events large enough to produce honey did not occur in 2010 or 2015.

There are other relationships that are not captured explicitly in Figure 13 but are important to consider. River red gums are highly regarded for their ability to support and sustain bee hives. When river red gums flower properly, they produce large amounts of pollen within a short two month window, December-January. This large quantity of pollen facilitates honey production and allows the bees to build their supplementary food stores within the hive. This supports the survival of the hives throughout the rest of the year, especially when they are placed within forests that produce less pollen. River red gums are also well known in the apiary industry for producing high quality pollen. The quality of pollen is important for bee health, longevity and productivity. Management and use of the GKP ecosystem for biomass for timber, firewood and recreation all act as potential pressures on the Apiary industry. Tree harvesting reduces the supply of floral resources available and management burns disrupt hive placements. The link between the ecosystem (quantity and quality), the biomass (quantity and quality), and the transactions are key components of the narrative. The quantity and quality of the assets can affect the quantity of all transactions both now and into the future.

A complete information set will capture each activity or transaction, estimate the potential value of those transactions, and link them to an ecosystem asset to understand how the attributes and condition of the ecosystem affects the transaction. Government can contribute to the set of information outlined in Figure 13 to support the ongoing management of the GKP ecosystem.

Figure 13 Floral resources for Honey



4.4.1 Literature review

Methods for calculating monetary supply and use for Honey are well established for exchange and welfare values. A range of methods have been used in contemporary calculations of monetary supply and use for honey based on exchange values. Not all exchange value calculations are consistent with the residual rents approach outlined in Figure 3. A collection of the approaches taken to analyse the value of honey production in Australia is outlined below:

- DELWP, Victorian Forests (2019): Used a residual rents approach to estimate the value of honey production (The State of Victoria Department of Environment Land Water and Planning, 2019)
- IDEEA, Forico (2018): Demonstrated a residual rents approach to estimating the value of honey production but actual valuation was outside the scope of their analysis (IDEEA Group, 2018)
- NCEconomics, Environmental Watering Victoria (2020): Used a residual rents approach to estimate the value of honey production (NCEconomics, 2020)
- CSIRO, Green Triangle (2020): did not measure the exchange value of honey production (Stewart et al., 2020)
- ANU, Central Highlands (2016): did not measure the exchange value of honey production (Keith et al., 2016)

As discussed in the biomass for timber and firewood literature reviews, welfare values could diverge from exchange values where market exchange values do not price in premiums that customers are willing to pay for native honey. For example, some literature shows that honey users are willing to pay premiums (rents) above the efficient market price for quality, local honey with high purity or antibacterial content (Karasinski, 2018). To the extent that this type of premium is not already captured in exchange values, welfare values will diverge from exchange values. Our view is that the premium here is likely to be negligible.

4.4.2 Method

Physical and monetary ecosystem service accounts were explored in this analysis. The biodiversity data outlined in the previous chapters was integrated and informed the ecosystem service accounts. A summary of the method for the physical supply and use and monetary supply and use is detailed below in the relevant sections.

Physical ecosystem service accounts – Floral resources for Honey

Method

The physical ecosystem accounts for floral resources for honey calculate the supply of honey from the GKP ecosystem within the target years. The estimation of physical ecosystem service accounts for floral resources for honey is as follows:

Spatial data for apiary licence sites were from open access datasets from DataVic (Department of Environment, Land, Water and Planning) and Forestry Corporation of NSW Apiary licence sites were identified within GKP forests. Licenced sites were considered to be the same in both years.

For all licensed areas vegetation characteristics were identified. Discussions with apiarist indicated river red gums were the key target species in GKP. The ecosystem type providing the services is Inland floodplain eucalypt forests and woodlands.

Discussions and interviews indicated apiarists were not accessing GKP in 2010 or 2015 due to the absence of major flowering events, potentially caused by continued dry conditions.

This structured approach incorporated significant amounts of on-ground ecological survey data from CSIRO and yield data from VicForests/NSW Forest Corp to ensure that the physical ecosystem service accounts closely reflect reality.

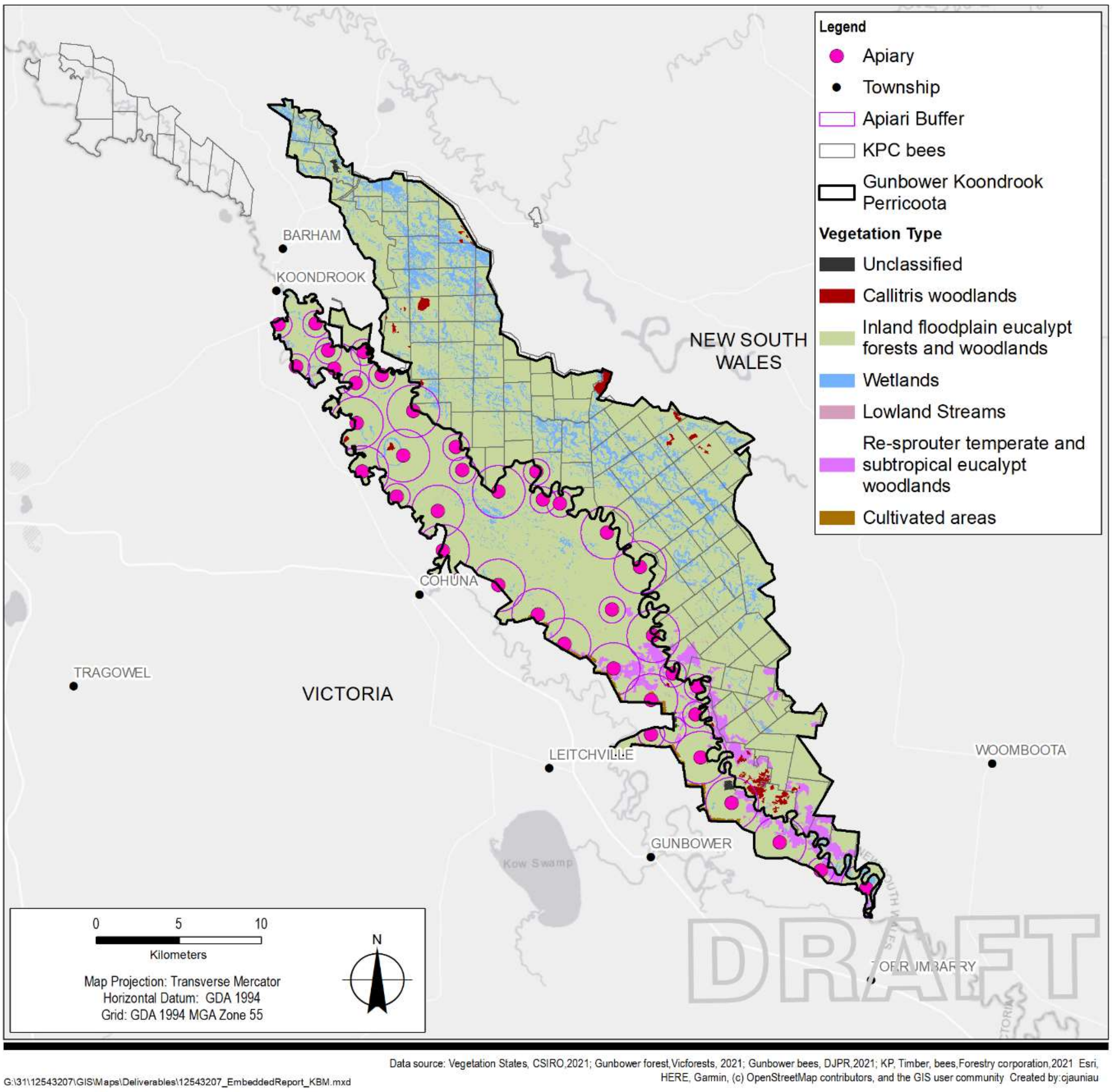


Figure 14 Apiary licence areas in Gunbower and Koondrook Perricoota forests

Estimates

Physical supply estimates were zero as the forests have not been utilised for honey supply in 2010 and 2015.

Monetary ecosystem service accounts – Floral resources for Honey

Method

It is understood that the GKP ecosystem was not utilised for honey production in 2010 or 2015 after extensive consultation with relevant government departments (Victorian Department of Environment, Land, Water and Planning (DELWP), Vic Forests, NSW Forestry Corporation), state and regional apiary associations (Victorian North Eastern Apiary Association (NEAA), New South Wales Apiary Association (NSWAA), and local apiarists within the region. As a result, the monetary supply of floral resources for honey in this evaluation is estimated to be zero. The method for calculating monetary ecosystem accounts for floral resources for honey is described in this chapter for future reference. The monetary ecosystem accounts calculate the exchange value of the ecosystem services determined under the physical ecosystem accounts. The ecosystem provision service of floral resources for honey can be valued by applying a residual rent dollar value to each tonne of honey yield in 2010 and 2015 respectively. This relationship is represented by:

$$\$ES_{h,y,i,t,e} = H_{y,i,t,z} * RR_{y,i,t}$$

Where:

$\$ES_{h,y,i,t,e}$ is the value of the honey harvest (h), in year (y), at geographic location (i), ecosystem type (t), measured as an exchange value (e)

$H_{y,i,t,z}$ is the honey yield (boxes) in year (y) from geographic location (i), ecosystem type (t) for quality (z)

$RR_{y,i,t}$ is the per unit (box) residual rent from honey in year (y) from location (i) from ecosystem type (t).

A general description of how monetary ecosystem accounts for floral resources for honey were produced is outlined below:

The floral resources supplied by the GKP ecosystem and the honey harvested by the apiary industry was interrogated.

The residual rents approach is used to determine the exchange value of the supply of floral resources for honey. Resource residual rent of honey harvested from the GKP ecosystem is the output price of honey less the input costs and depreciation costs. Importantly, resource rent is not the revenue from the sales exchange, nor the gross operating surplus. These valuations will overstate the residual resource rent attributable to the floral resources for honey and are not directly comparable to the methods and valuations for GKP as a result.

The residual rents per unit of honey supply is multiplied by the physical supply units to determine the exchange value. This process identifies the exchange value for honey on the competitive market. There is a chance that consumers assign a premium to native honey sourced from the GKP ecosystem and are willing to pay more for it in a competitive market. This would be captured as a welfare value. In principle, the two prices will collapse onto each other if we are operating in a competitive market. This follows the basic principle that supply equals demand and should ensure that this analysis fully captures consumer surplus.

The methods used to define the physical and monetary ecosystem accounts for honey are consistent with or extend methods used or proposed in Australian EEA and natural capital assessments (UNCEEA, 2021a)

Estimates

Monetary supply and use estimates for the GKP ecosystem were zero as the forests were not utilised for honey supply in 2010 and 2015.

4.4.3 Areas for improvement

Access to data was a significant limitation in the analysis of annual floral resources and the resulting honey yield from the GKP ecosystems. No central database of apiarists that place hives in the GKP ecosystem was available from either VIC Forests or NSW Forest Corp. Similarly, no official record of honey yield from the Gunbower, Koondrook or Perricoota forests is maintained. As a result, the flowering events and annual honey yields from the GKP ecosystem relied on reports from individual apiarists that are known to place hives in the area. Government departments and organisations consulted with include, but is not limited to, the Victorian Department of Environment, Land, Water and Planning (DELWP), Vic Forests, Victorian North Eastern Apiary Association (NEAA), New South Wales Apiary Association (NSWAA), NSW Forestry Corporation.

The influence that natural flooding and environmental water events has on flowering events within the GKP ecosystem is difficult to quantify. Climate, hydrological conditions, and landscape position all influence supply and quality of ecosystem characteristics and flowering events. Future assessments of ecosystem services should also identify critical characteristics, drivers, transitions that could be incorporated into the GKP AusEcoModels conceptual models. These can form a basis for coherence and monitoring in future to support ongoing ecosystem service accounts. Obviously this would need to be prioritised and consolidated according to user need and data availability.

Further investigation in consultation with apiarists will assist defining the role of environmental watering, climate and natural events play in large flowering events. This is not a shortcoming of the approach taken to produce the physical and monetary ecosystem accounts, but a representation of the research needed to fully understand the impact of natural and environmental watering on ecosystem characteristics.

4.4.4 Accounting outputs

A honey physical supply and use table (Table 19) and monetary supply and use table (Table 20) was developed for the accounting area. Supply and use tables show the relationship between floral resources for honey supplied, the GKP ecosystem, and the industry as the user.

Since 2000, local apiarist report that flowering events in the GKP ecosystem have not been as large or as frequent as they were in the decades prior. Prior to 2000, local apiarists report that river red gums in the GKP forests flowered on an approximately two-year cycle. Since 2000, a large flowering event had not occurred in the GKP until the 2020/21 season. Apiarists have been taking their hives elsewhere to produce honey. The 2015 physical supply and use (Table 19) and monetary supply and use (Table 20) tables are empty to reflect that no flowering events occurred in 2010 or 2015 and apiarists could not utilise the resource.

Table 19 Floral resources for Honey physical supply and use table, GKP, 2010 and 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply/ Use	**Units**	**Household**	**Government**	**Industries**	**Fire-intolerant *Callitris* woodlands**	**Inland floodplain eucalypt forests and woodlands**	**Wetlands**	**Cultivated areas**	**Re-sprouter temperate and subtropical eucalypt woodlands**	**Lowland Streams**	**Fire-intolerant *Callitris* woodlands**	**Inland floodplain eucalypt forests and woodlands**	**Wetlands**	**Cultivated areas**	**Re-sprouter temperate and subtropical eucalypt woodlands**	**Lowland Streams**
2010																
Supply	kg				-	-	-	-	-	-	-	-	-		-	-
Use	kg			-												
2015																
Supply	kg				-	-	-	-	-	-	-	-	-		-	-
Use	kg			-												

Note: Supply and use of floral resources for honey was derived from extensive consultation with apiarists known to place hives in the GKP ecosystem. The location of apiary sites within the GKP ecosystem was provided by Vic Forests (G) and NSW Forest Corp (KP). There are around 140 sites available for apiarists to place hives on across the Gunbower, Koondrook and Perricoota forests. Confidence in data is moderate. The consulted apiarist were renting the rights to access at least 40 of these sites across the GKP ecosystems in 2010 and 2015. This represent a significant proportion of the apiary sites available for rent in the GKP ecosystem and demonstrates the extent of stakeholder consultation. Estimates can be improved with systematic collection of honey yield data based on site ownership data held by NSW Forest Corp and Vic Forests. '–' = 0
Source: Data from (NSW Forest Corp 2021, Vic Forests 2021, stakeholder consultation)

Table 20 Floral resources for Honey monetary supply and use summary table, GKP, 2010 and 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply/ Use	Units	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
2010																
Supply	$ AUD				-	-	-	-	-	-	-	-	-		-	-
Use	$ AUD			-												
2015																
Supply	$ AUD				-	-	-	-	-	-	-	-	-	-	-	-
Use	$ AUD			-												

Note: Monetary supply and use from floral resources for honey are derived from residual rent estimates in 2010 and 2015 and are presented in real terms ($AUD 2020/21). Residual rents are the total monetary output less the costs of honey harvest and depreciation. Confidence in estimates is moderate. Honey royalties were derived from extensive consultation with apiarists known to place hives in the GKP ecosystem. There are around 140 sites available for apiarists to place hives on across the Gunbower, Koondrook and Perricoota forests. The consulted apiarist were renting the rights to access at least 40 of these sites across the GKP ecosystems in 2010 and 2015. This represent a significant proportion of the apiary sites available for rent in the GKP ecosystem and demonstrates the extent of stakeholder consultation. Estimates of exchange value of honey yield can be improved with official recording of annual yields, sale price and harvest cost data. '–' = 0

Source: Data from (NSW Forest Corp 2021, Vic Forests 2021, stakeholder consultation)

4.5 Global climate regulation services - Carbon sequestration and carbon retention

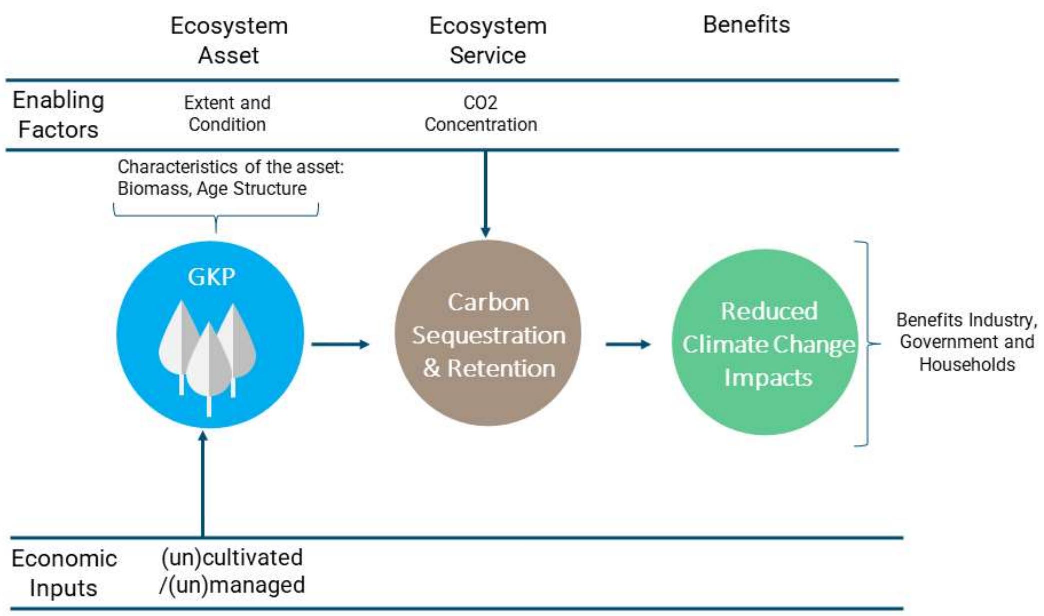
The GKP ecosystem provides global climate regulation services through carbon sequestration and the retention of carbon stocks (carbon retention). This service can be quantified in terms of the tonnes of carbon sequestered per annum and tonnes of carbon retained in biomass in the Gunbower, Koondrook and Perricoota forests. Following the SEEA EA, the user of global climate regulation services is the national government, who are treated as using the service on behalf of the Australian and global communities who benefit from the reduced impacts of climate change.

As shown in Figure 15, the GKP ecosystem sequesters and retains carbon in biomass. Simplistically, the volume of carbon that the GKP ecosystem can sequester from the atmosphere and retain is a function of the carbon dioxide levels in the atmosphere, and the extent and condition of the biotic components within the GKP ecosystem.

There are other relationships that are not captured explicitly in Figure 15 but are important to consider in the management of carbon sequestration and retention within the GKP ecosystem. Mature trees that provide global climate regulation services are an asset for species within the forest ecosystem and contribute to the user experience (for example, camping). Timber and firewood harvesting, and coupe management activities like undergrowth clearing and burning are all likely to act as a negative pressure on the GKP ecosystem's ability to sequester and retain carbon. The link between the ecosystem (quantity and quality), the biomass (quantity and quality), and the transactions are key components of the narrative.

A complete information set will capture each activity or transaction, estimate the value of those transactions, and link them to an ecosystem asset to understand how the attributes and condition of the ecosystem affect the transaction. Government can contribute to the set of information outlined in Figure 15 to support the ongoing management of the GKP ecosystem.

Figure 15 Carbon sequestration and retention



4.5.1 Literature review

The Full Carbon Accounting Model (FullCAM) is a calculation tool for modelling Australia's greenhouse gas emissions from the land sector. FullCAM has been primarily used to provide carbon retention and sequestration reporting for National Greenhouse Accounts. FullCAM was considered appropriate for terrestrial ecosystem types at GKP it is currently not suitable for wetland carbon estimates. Carnell et al (2018) had surveyed wetlands across ten catchment management authority regions and analysed carbon retention and sequestration rates. These estimates were used as the basis for calculating wetland retention and sequestration rates for the wetland ecosystem type at GKP.

FullCAM is also currently used for emissions reduction fund projects for forestry plantations, reforestation by environmental or mallee plantings. FullCAM was used to estimate above and below ground biomass, carbon retention and carbon sequestration.

There are three established methods for valuing carbon sequestration Carbon Pricing, Social Cost of Carbon, Shadow Price of Carbon. The different carbon sequestration valuation methods are outlined below.

- **Carbon Pricing.** Carbon pricing represents the idea that to achieve a reduction in carbon, the carbon price should be equal to the marginal abatement cost (MAC) in the accounting period – i.e. the cost of reducing carbon emissions by one unit (Stern, 2008). In schemes where there is a cap on the quantity of emissions and where the carbon price is determined by market forces (for example, in an emissions trading scheme), the observed carbon price represents the marginal private abatement cost to producers of carbon emissions, and hence, the marginal private benefit of sequestering carbon (IDEEA Group, 2018).
- **Social Cost of Carbon (SCC).** The SCC represents the economic value of the damage caused by the emission of a marginal tonne of carbon into the atmosphere (Ninan & Kontoleon, 2016). This method focuses on valuing the economic and social damages arising from changes in weather patterns and associated natural disasters that can be associated with carbon emissions. In contrast to the carbon price, this non-market valuation method represents the marginal social cost of producing carbon emissions or the marginal social benefit (avoided costs) of sequestering carbon (IDEEA Group, 2018).
- **Shadow price of carbon (**SPC**).** The shadow price of carbon is based on the SCC "for a given stabilisation goal, adjusted to reflect estimates of the MAC required to take the world onto a defined stabilisation goal and other factors that may impact Australian willingness to pay for reductions.

Approaches for valuing carbon using carbon pricing (exchange) and social cost of carbon (welfare) in the context of EEA are included in (United Nations Department of Economic and Social Affairs Statistics Division, 2021). Refer to this document for fuller discussion.

4.5.2 Method

Measuring and reporting global climate regulation services within the SEEA EA framework is an ongoing area of research and testing although a clear set of principles has been articulated. In this analysis, physical and monetary ecosystem service accounts were compiled only for the carbon sequestration component of the global climate regulation service, where carbon sequestration is defined as the flow of carbon from the atmosphere into carbon stocks within the GKP ecosystem. Carbon stocks are defined as the total existing stock of carbon within plant biomass in the GKP ecosystem. Beyond measurement of ecosystem services, measures of the carbon stock within the GKP ecosystem are important for policy and management decision making and hence these are presented in Table 33 to supplement the analysis.

A particular focus of was to integrate the account ready extent and condition data outlined in companion technical reports (Mokany et al., 2021; Richards AE et al., 2021b; Richards AE et al., 2021a; Richards AE et al., 2021c), characterising measures of carbon sequestration and carbon stock by the different habitat types identified across the study area. A summary of the method for the physical and monetary supply and use is provided below. The welfare value of the monetary supply and use sits outside the SEEA EA and is outlined separately below. Detailed methods for both ecosystem service accounts are outlined below. All datasets relied on for the analysis of ecosystem services are referenced at the bottom of the account tables.

Physical ecosystem service accounts – Carbon sequestration and carbon stocks

Method

The physical ecosystem accounts calculate carbon sequestration and carbon stocks for terrestrial vegetation and wetlands. The estimation of physical ecosystem service accounts for carbon sequestration and stocks is as follows:

The spatial area of carbon sequestration was defined within the boundaries of GKP. This included all ecosystem states present within the GKP.

Characteristics of the ecosystem state and expression providing the sequestration services were identified for both Gunbower and Koondrook Perricoota. The extent of services covered both terrestrial and wetland ecosystems.

Terrestrial vegetation carbon stocks and sequestration

FullCAM (public release version 2020) was used to calculate carbon sequestration for ecosystem types including inland floodplain Eucalypt forests and woodlands, *Callitris*, Black box. It was recognised that default FullCAM maximum above ground biomass for GKP were much lower much lower than data provided in site vegetation monitoring programs. This was confirmed with a review of vegetation characteristics data provided by CSIRO (Prober et al., 2021) and discussions with the Department of Industry Science and Resources (DISER - Tim Liersch, pers comm). Estimates were made for above and below ground living and dead biomass. Soil carbon was not included.

It was identified that calculation of sequestration rates for GKP should incorporate the ecosystem characteristics of the site as defined by Prober et al., (2021). It was determined ecosystem expressions were most suitable as they differentiated between ecosystem states and data estimates for characteristics such as above ground biomass were available for most expressions.

For each terrestrial ecosystem expression, vegetation characteristics in FullCAM were reviewed against the CSIRO vegetation characteristics and were modified to reflect site specific data. FullCAM attributes modified included initial trees, maximum above ground biomass, maximum and average tree age, standing dead biomass. To define the mass of initial trees the percentage estimate in FullCAM was used to convert the site specific above ground biomass estimate to mass of stems, branches, leaves etc. A summary of the modifications are provided below (Table 21).

For each ecosystem expression a range of locations (between 10 and 50) were selected that reflected geographic coverage of the particular ecosystem expression in Gunbower Forest and Koondrook Perricoota forests. These sites were input to FullCAM as plot digest files. Carbon sequestration rate calculations used a time series of 1990 to 2020.

To also define carbon reductions timber harvest locations between 2010 and 2015 were further assessed to identify locations of harvest and areas of vegetation harvested. This data was used as an input of annual event to FullCAM. Actual percentages of thinning for the Inland Eucalypt Floodplain Forest and Woodland ecosystem type were very low 2-3% of the total area and were much lower than the default FullCAM setting of 25%. There is some uncertainty in the accuracy of FullCAM accounting for these reductions.

Mass of carbon stock and sequestration rates was estimated based on area occupied by ecosystem expressions in 2010 and 2015. FullCAM results for each expression were averaged and carbon retention and sequestration rate was calculated based on the area occupied in 2010 and 2015 of each ecosystem expression (Table 21). The calculation of carbon retention and sequestration rate included above and below ground live and dead biomass but did not include soil carbon in the accounts. For a comprehensive list of ecosystem expressions within the GKP ecosystem please refer to Table 3.

Table 21 GKP terrestrial ecosystem expressions and characteristics used to modify FullCAM default settings reflecting local site characteristics. Ecosystem characteristics have been sourced from (Prober et al., 2021) and where suitable used to update FuLLCAM default settings for GKP.

	Live biomass				**Dead biomass**		
	Ecosystem Characteristics (Prober et al., 2021)	FuLLCAM		**Input to FullCAM**	Ecosystem Characteristics (Prober et al., 2021)	GHD estimate	**Input to FullCAM**
Ecosystem expression (Prober et al., 2021)	**above ground live biomass (t/ha)**		Proportion	**Average mass (t/ha)**	**Standing dead biomass (t/ha)**	Proportion	**Average mass (t/ha)**
Mature floodplain eucalypt forests & woodlands	**233**				46		
		Stems	0.28	**65.24**		0.31	**14.35**
		Branches	0.22	**51.26**		0.25	**11.27**
		Bark	0.08	**18.64**		0.06	**2.73**
		Leaves	0.07	**16.31**		0.04	**1.78**
		Coarse Roots	0.27	**62.91**		0.30	**13.83**
		Fine roots	0.08	**18.64**		0.04	**2.04**
Reduced tree canopy with wetland, grassland or chenopod understorey	**117**				31		
		Stems	0.28	**32.76**		0.31	**9.67**
		Branches	0.22	**25.74**		0.25	**7.60**
		Bark	0.08	**9.36**		0.06	**1.84**
		Leaves	0.07	**8.19**		0.04	**1.20**
		Coarse Roots	0.27	**31.59**		0.30	**9.32**
		Fine roots	0.08	**9.36**		0.04	**1.37**
Invaded mature floodplain eucalypt forests & woodlands / Reduced tree canopy over invaded understorey	**233**				78		
		Stems	0.28	**65.24**		0.31	**24.33**
		Branches	0.22	**51.26**		0.25	**19.11**
		Bark	0.08	**18.64**		0.06	**4.62**
		Leaves	0.07	**16.31**		0.04	**3.02**
		Coarse Roots	0.27	**62.91**		0.30	**23.46**
		Fine roots	0.08	**18.64**		0.04	**3.46**
Dense pole-stage eucalypt stands	**89**				78		
		Stems	0.28	**24.92**		0.31	**24.33**
		Branches	0.22	**19.58**		0.25	**19.11**
		Bark	0.08	**7.12**		0.06	**4.62**
		Leaves	0.07	**6.23**		0.04	**3.02**
		Coarse Roots	0.27	**24.03**		0.30	**23.46**

	Live biomass				Dead biomass		
	Ecosystem Characteristics (Prober et al., 2021)	FuLLCAM		**Input to FullCAM**	Ecosystem Characteristics (Prober et al., 2021)	GHD estimate	**Input to FullCAM**
Ecosystem expression (Prober et al., 2021)	**above ground live biomass (t/ha)**		Proportion	**Average mass (t/ha)**	**Standing dead biomass (t/ha)**	Proportion	**Average mass (t/ha)**
		Fine roots	0.08	**7.12**		0.04	**3.46**
Grey-box shrub-grass woodland with exotic understorey	**99**	Stems	0.28	**27.72**			
		Branches	0.22	**21.78**			
		Bark	0.08	**7.92**			
		Leaves	0.07	**6.93**			
		Coarse Roots	0.27	**26.73**			
		Fine roots	0.08	**7.92**			

Wetland carbon retention and sequestration

FullCAM does not assess wetland carbon retention and sequestration rates. Wetland stock and sequestration estimates were conducted using average wetland values for Victorian wetlands arising from a state-wide assessment of wetlands (Carnell et al., 2018). Wetland retention and sequestration estimates were provided as average and range as Mega grams C Ha^{-1} $year^{-1}$.

Carnell et al., (2018) classified wetlands sampled according to the Corrick system (Corrick, 1981, 1982; Corrick & Norman, 1976; Corrick & Norman, 1980). The Corrick wetland classification system has been widely used in Victoria. Corrick classifications were aligned with ecosystem expressions (defined according to the AusEcoModels framework) to allow adoption of the carbon stocks and sequestration estimates from Carnell et al., (2018).

Carbon sequestration rates for wetlands at GKP were calculated based on area of wetland ecosystem types in 2020 and 2015 and average values from Carnell et al., (2018).

Estimates

Carbon stock and sequestration estimates for wetlands in Victoria (Carnell et al., 2018) were aligned with the extent of wetland ecosystem expressions (Richards et al 2021a).

Table 22 Carbon stock estimates and based on Carnell et al., 2018 state-wide assessment of Victorian wetlands

Corrick wetland classification	Carnell et al (2018) C estimates Mg C_{org} ha^{-1}	Ecosystem state (Prober et al., 2021)	Ecosystem expression (Prober et al., 2021)	Carbon retention estimate used in calculations[1] Mg C_{org} ha^{-1}
Shallow and deep freshwater marsh	200 +/- 200 Mg (shallow) and 230 +/- 190 (deep)	High condition wetland	High condition wetland	200
Permanent open freshwater	110 +/- 120	Moderate- and low-condition wetlands	Permanent wet (moderate or low condition)	110
Shallow and deep freshwater marsh	200 +/- 200 Mg (shallow) and 230 +/- 190 (deep)	Moderate- and low-condition wetlands	Semi permanent wet (moderate or low condition)	120[2]
Freshwater meadows	130 +/- 100	Moderate- and low-condition wetlands	Temporary wet (moderate or low condition)	104[3]

1 Mg = mega gram equivalent to 1 tonne

2 Based on 60% of the average carbon stock estimate for shallow and deep freshwater marshes to reflect lower condition and biomass of aquatic vegetation

3 reflected as 80% estimate of freshwater meadow average carbon stock as a moderate or low condition wetland

Table 23 Carbon sequestration rate estimates and based on Carnell et al., 2018 state-wide assessment of Victorian wetlands

Corrick wetland classification	Carnell et al (2018) C estimates Mg C_{org} ha^{-1} yr^{-1}	Ecosystem state	Ecosystem expression	Carbon sequestration estimate used in calculations[1] Mg C_{org} ha^{-1} yr^{-1}
Shallow and deep freshwater marsh	0.91 +/- 0.27 (shallow) 1.6 +/- 0.5 (deep)	High condition wetland	High condition wetland	1.28
Permanent open freshwater	2.3 +/- 0.7	Moderate- and low-condition wetlands	Permanent wet (moderate or low condition)	1.84[1]
Shallow and deep freshwater marsh	0.91 +/- 0.27 (shallow) 1.6 +/- 0.5 (deep)	Moderate- and low-condition wetlands	Semi permanent wet (moderate or low condition)	0.72[2]
Freshwater meadows		Moderate- and low-condition wetlands	Temporary wet (moderate or low condition)	0.72[3]

1 Mg = Mega gram equivalent to 1 tonne
2 based on 60% of the average carbon sequestration estimate for shallow and deep freshwater marshes to reflect lower condition and biomass of aquatic vegetation
3 reflected as 80% estimate of freshwater meadow average carbon sequestration as a moderate or low condition wetland

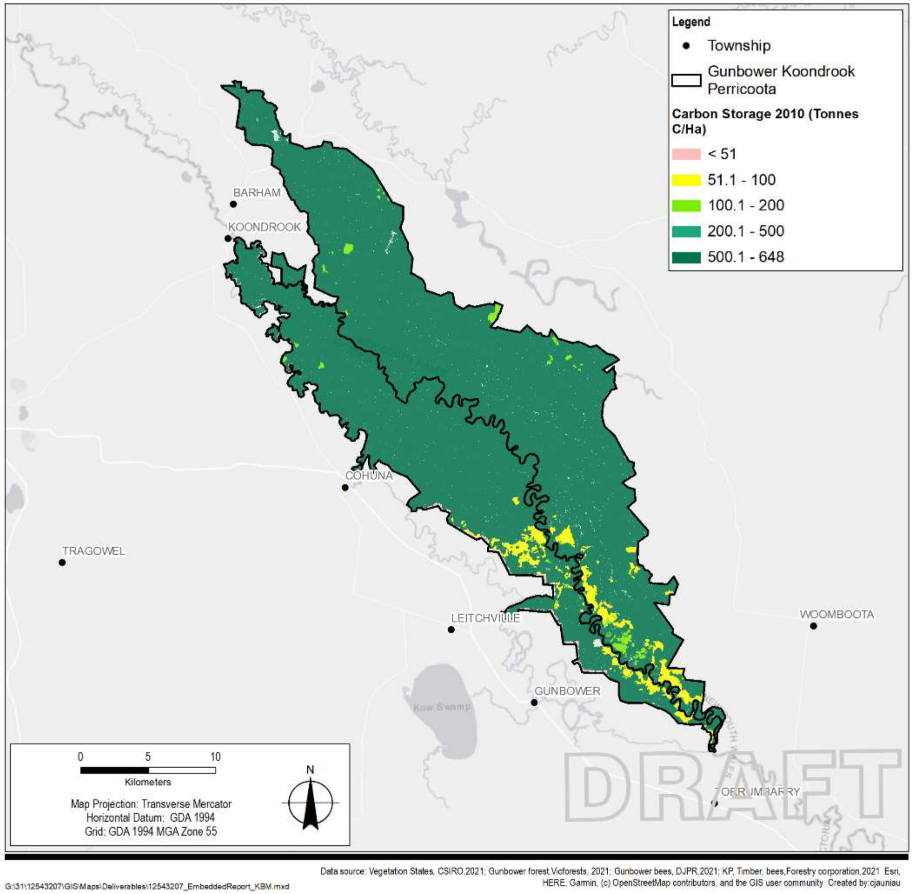


Figure 16 Distribution of carbon stock (relative comparison) across ecosystem types at GKP. (Units tonnes Carbon per Ha)

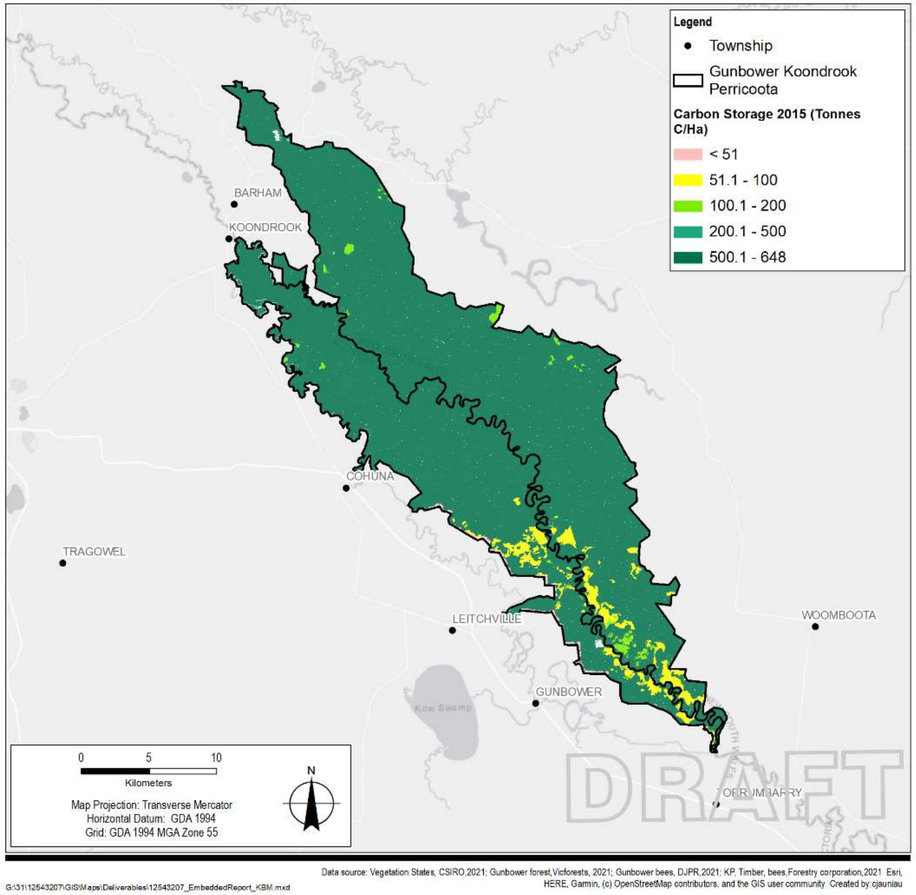


Figure 17 Distribution of carbon stock (relative comparison) across ecosystem types (Units tonnes Carbon per Ha)

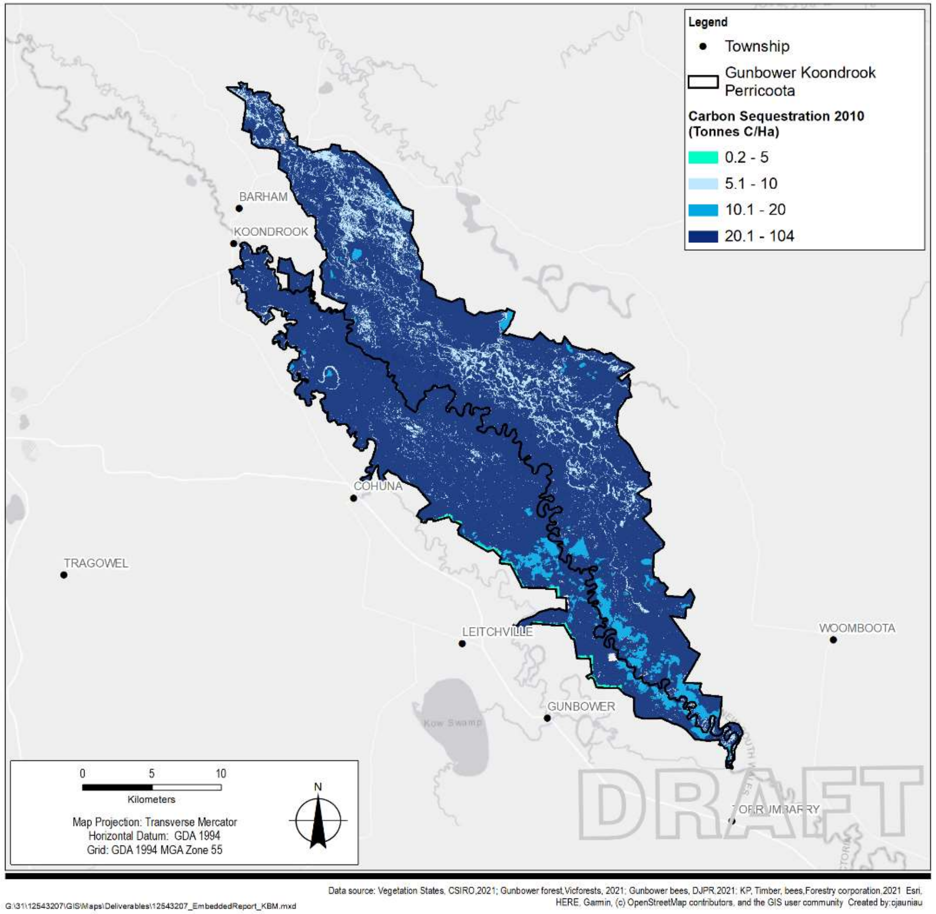


Figure 18 2010 carbon sequestration rates for ecosystem types at GKP. (Units tonnes Carbon Ha^{-1} yr^{-1})

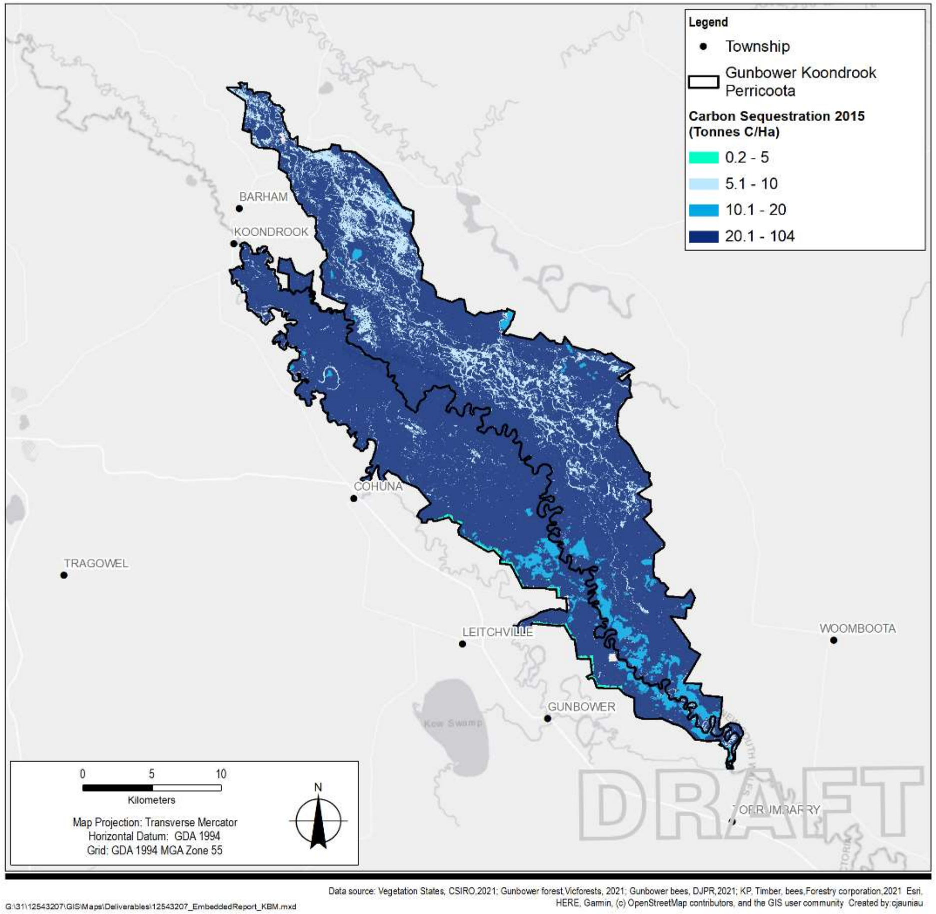


Figure 19 2015 carbon sequestration rates for ecosystem types at GKP. (Units tonnes Carbon Ha^{-1} yr^{-1})

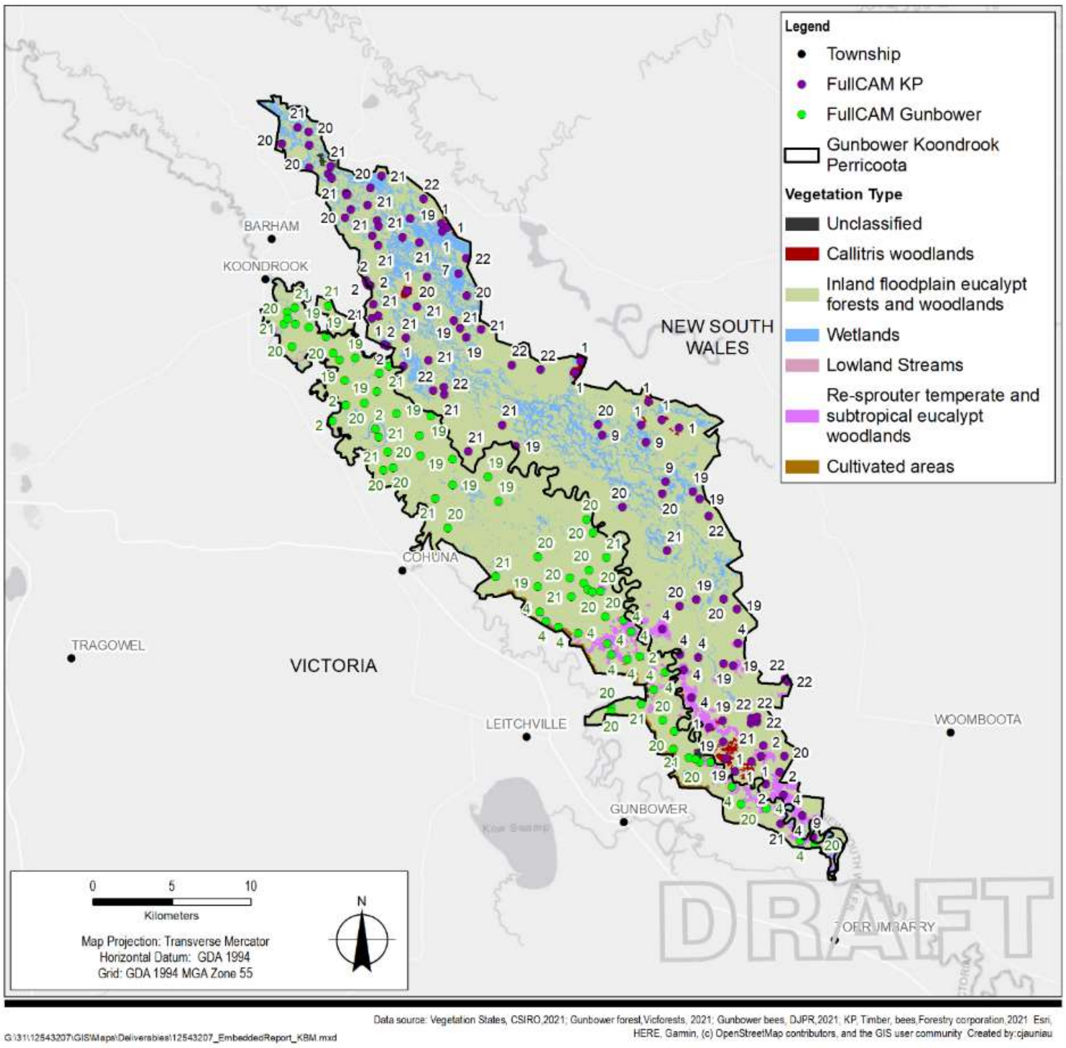


Figure 20 GKP FullCAM carbon sequestration modelling sites. Numbers indicate different ecosystem types

Monetary ecosystem service accounts – Carbon sequestration

Method

The monetary ecosystem accounts for carbon sequestration calculate the exchange value of the sequestered carbon. Note that the value of carbon stock is not included in this analysis. The welfare value of carbon sequestration is also calculated for comparison and is outlined separately below. The ecosystem provision service of carbon sequestration can be valued by applying an exchange value to each tonne of carbon dioxide equivalent (CO_2e) sequestered in 2010 and 2015 respectively. This relationship is represented by:

$$\$ES_{c,y,i,t,e} = C_{y,i,t} * 3.664 * EVC_y$$

Where:

$\$ES_{c,y,i,t,e}$ is the value of the carbon sequestration service (c), in year (y), at geographic location (i), ecosystem type (t), measured as an exchange (e) value

$C_{y,i,t}$ is the carbon tonne from the service in year (y) from location (i)

3.664 is the conversion from carbon to CO_2e

$EVC_{y,}$ is the exchange value of carbon in year (y). This analysis used two exchange values of carbon, the weighted average Australian Carbon Credit Unit price for year y and the median price of carbon on international markets in year (y), as reported on the World Bank Carbon Pricing Dashboard (Australian Government Clean Energy Regulator, 2020; Regulator, 2020).

A general description of how the monetary ecosystem accounts for carbon sequestration were produced is outlined below:

The carbon supplied to government by the GKP ecosystem was interrogated and the results are summarised in Table 24 below. Detailed supply of carbon by each different ecosystem type is presented in Table 35.

Table 24 Carbon supplied by Gunbower and Koondrook-Perricoota Ecosystems

			Ecosystem		
Carbon	Year	Unit	Gunbower	Koondrook-Perricoota	Total
Supply	2010	tonnes	383,363	639,445	1,022,807
Supply	2015	tonnes	411,397	619,375	1,030,771

The exchange value approach was used to value carbon sequestration within the GKP ecosystem. There are a variety of exchange values available for carbon. Carbon pricing represents the idea that to achieve a reduction in carbon, the carbon price should be equal to the marginal abatement cost (MAC) in the accounting period – i.e. the cost of reducing carbon emissions by one unit (Stern, 2008). In schemes where there is a cap on the quantity of emissions and where market forces determine the carbon price (for example, in an emissions trading scheme), the observed carbon price represents the marginal private abatement cost to producers of carbon emissions, and hence, the marginal private benefit of sequestering carbon.

In this analysis, two exchange values were used. The first was the weighted average of ACCUs in year (y) within the Commonwealth's Emissions Reduction Fund. The second exchange value used was the median price of carbon from international markets in year (y) as reported on the World Bank Carbon Pricing Dashboard. These exchange values are presented below:

Table 25 Carbon exchange values

	Weighted average price ACCU's purchased		World Bank Global median carbon exchange price	
	2010	2015	2010	2015
Carbon Exchange value (AUD$/t CO2e)	12.72	13.10	18.82	24.76

The monetary estimates are calculated using two independent exchange prices of carbon sequestration. This is necessary because Australia does not have an explicit price on carbon. The

World Bank Global median carbon exchange price is preferred for carbon valuation as these values reflect prices for carbon based on observed market transactions. Market prices provide an accurate exchange value of carbon and allow more reliable calculation of the resulting benefit to local, national, and global beneficiaries. In comparison, the ACCU exchange value is derived from the funding awarded to projects by the Commonwealth's Emissions Reduction Fund. The weighted average price of ACCU's purchased represents a proxy for carbon prices in Australia but does not explicitly represent an exchange value. If policy analysis required use of an Australian exchange value in the creation of Environmental Economic Accounts, the ACCU value could be relied on as an approximate estimate of $/t CO2e.

The Commonwealth's Emissions Reduction Fund (ERF) has been operational since April 2015. 11 ACCU auctions have been held by the ERF between April 2015 and September 2020. The historical weighted average cost of ACCUs when purchased by the Commonwealth through the ERF is outlined in Table 26.

Table 26 Emissions Reduction Fund

Auction Date	Weighted average price ACCU's ($AUD)	Tonnes of abatement (millions)	Contracts awarded	Total contract value ($Millions)
Apr-15	13.95	47	107	660
Nov-15	12.25	45	129	556
Apr-16	10.23	50	73	516
Nov-16	10.69	34	49	367
Apr-17	11.82	11	31	133
Dec-17	13.08	8	26	104
Jun-18	13.52	7	32	90
Dec-18	13.87	3	34	45
Jul-19	14.17	1	3	1
Mar-20	16.14	2	12	28
Sep-20	15.74	7	35	110

Source: http://www.cleanenergyregulator.gov.au/ERF/Auctions-results

The average weighted average price of ACCUs bought by the Commonwealth in 2015 was calculated to determine the exchange value of carbon sequestration in 2015. The exchange value for 2010 is estimated using a weighted average of the total emission reduction fund auction ACCU prices. This is an estimation because the ERF was not operational in 2010. The calculated exchange values are presented in Table 25.

Physical supply of carbon from the GKP ecosystem is presented in tonnes. The exchange value of carbon dioxide sequestration identified from the ERF are applied to the carbon dioxide that the ecosystem can sequester. Tonnes of physical carbon supplied by the GKP ecosystem is converted to carbon dioxide equivalent units (CO_2e) using the Carbon to CO_2e factor (Table 27). The monetary value of carbon sequestration from the GKP ecosystem in 2010 and 2015 is the product of the associated exchange value and the CO_2e that the ecosystem sequesters. Total monetary supply for the GKP ecosystem is presented in Table 27 below.

Table 27 Emissions Reduction Fund Exchange Value – Monetary Supply

	Carbon (tonnes)	Carbon to Co2e factor	Weighted average price ACCU's purchased ($AUD/t CO2e)	Total Monetary Supply
2010	1,022,807	3.664	12.72	47,671,100
2015	1,030,771	3.664	13.10	49,475,300

The second exchange value of carbon sequestration relies on the median price of existing international carbon market values. The median price for units of carbon dioxide equivalent (CO_2e) across international Carbon Markets or Emissions Trading Schemes (ETS) are reported on the World Bank Carbon Pricing Dashboard (World Bank, 2020). A summary of the international price data is presented in Table 28. The median international price was calculated for 2010 and 2015 to avoid the influence of outliers on the analysis.

Table 28 International Exchange Values of Carbon

Jurisdiction Covered	Instrument Type	2010 ($US/t CO2e)	2015 ($US/t CO2e)
Alberta	ETS	14.89	11.89
British Columbia	Carbon tax	19.85	23.79
Denmark	Carbon tax	27.96	24.47
EU, Norway, Iceland, Liechtenstein	ETS	17.27	7.69
Estonia	Carbon tax	2.71	2.15
Finland	Carbon tax	27.49	62.38
Iceland	Carbon tax	8.51	16.01
Ireland	Carbon tax	20.20	21.51
Latvia	Carbon tax	0.76	3.76
Liechtenstein	Carbon tax	34.21	37.17
New Zealand	ETS	12.44	4.93
Norway	Carbon tax	62.03	53.96
Poland	Carbon tax	0.08	0.08
RGGI - United States	ETS	2.30	5.90
Slovenia	Carbon tax	16.83	18.58
Sweden	Carbon tax	145.48	129.81
Switzerland	ETS	0.00	12.39
Switzerland	Carbon tax	34.21	61.96
Tokyo	ETS	0.00	37.52
Median		17.27	18.58

Note: Exchange value is presented in US/t CO2e as displayed on the World Bank Carbon Pricing Dashboard (accessed January 2021). Confidence in data is high.

Source: World Bank Carbon Pricing Dashboard (Bank, 2021; The World Bank, 2021)

The median international price of CO_2e supply was converted from $USD to $AUD in 2010 and 2015 (Table 29). These prices were adopted as the exchange values for this part of the analysis.

Table 29 International exchange values of Carbon - $AUD

	Median international exchange values carbon	
	$USD/t CO2e	$AUD/t CO2e
2010	17.27	18.82
2015	18.58	24.76

Physical supply of carbon from the GKP ecosystem is presented in tonnes. The exchange value of carbon dioxide sequestration identified from International prices are applied to the carbon dioxide that the ecosystem can sequester. Tonnes of physical carbon supplied by the GKP ecosystem is converted to carbon dioxide equivalent units (CO_2e) using the Carbon to CO_2e factor (Table 30). The monetary value of carbon sequestration from the GKP ecosystem in 2010 and 2015 is the product of the associated exchange value and the CO_2e that the ecosystem sequesters. Total monetary supply for the GKP ecosystem is presented in Table 30.

Table 30 World Bank Exchange Value - Monetary supply

	Carbon (tonnes)	Carbon to CO2e factor	Exchange Value ($AUD/t CO2e)	Total Monetary Supply
2010	1,022,807	3.664	18.82	70,528,900
2015	1,030,771	3.664	24.76	93,506,400

Approach to producing the welfare value of carbon sequestration

The welfare value of carbon sequestration was also calculated for comparison. The welfare value is not a direct exchange and, as a result, sits separate from the ecosystem physical and monetary supply and use tables. The welfare value is presented here to demonstrate the potential gap between the value the market currently places on carbon sequestration and the benefits available from carbon sequestration for society. This is important because the market for carbon sequestration, and the exchange values they produce, are heavily influenced by political sentiment. In comparison, the contemporary literature modelling welfare values attempts to calculate the social cost of carbon from a scientific basis.

It is important to note that modelling of the social cost of carbon is highly sensitive to the assumptions made, including discount rate, damage functions, population with-standing, and uncertainty. Because the amount of damage caused by each incremental unit of carbon in the atmosphere depends on the concentration of atmospheric carbon today and in the future, the SCC varies according to the emissions and concentration trajectory the world is on (Department of Energy & Climate Change, 2009). A significant limitation of the SCC modelling relied on for this analysis is a failure to account for the impacts of exceeding environmental tipping points. Exceeding environmental tipping points is expected to cause abrupt and irreversible damages with large market and non-market impacts (Cai et al., 2015). SCC modelling that does not include the risk of environmental tipping points is likely to underestimate the true SCC (Cai et al., 2015).

The welfare value of carbon sequestration is valued by applying the social cost of carbon (SCC) to each tonne of carbon dioxide equivalent (CO_2e) sequestered in 2010 and 2015 respectively. The SCC represents the economic value of the damage caused by the emission of a marginal tonne of carbon into the atmosphere. This relationship is represented by:

One tonne of carbon is equal to 3.664 tonnes of CO2e (Department of the Environment and Energy, 2020). Such that:

$$\$ES_{c,y,i,t,w} = C_{y,i,t} * 3.664 * SCC_{y,}$$

Where:

$\$ES_{c,y,i,t,w}$ is the value of the carbon sequestration service (c), in year (y), at geographic location (i), ecosystem type (t), measured as a welfare (w) value

$C_{y,i,t,}$ is the carbon tonne from the service in year (y) from location (i), ecosystem type (t)

3.664 is the conversion from carbon to CO_2e

$SCC_{y,}$ is the social cost of carbon (SCC) for year (y).

A general description of how the welfare value of carbon sequestration was produced is outlined below:

The carbon (tonnes) supplied by the GKP ecosystem was interrogated. This is summarised in Table 24 above. Detailed supply of carbon by each different ecosystem type is presented in Table 35.

The welfare value approach focuses on valuing the economic and social damages arising from changes in weather patterns and natural disasters that can be associated with carbon emissions. In contrast to the carbon price (exchange value), this non-market valuation method represents the marginal social cost of producing carbon emissions or the marginal social benefit (avoided costs) of sequestering carbon.

This analysis relies on the SCC estimated by the United States Environmental Protection Agency (EPA) in 2016 (Interagency Working Group on the Social Cost of Greenhouse Gases 2016).

Table 31 Average Social Cost of Carbon (2.5% discount rate)

	($USD 2007/t CO2e)	($AUD 2007/t CO2e)	($AUD/t CO2e)
2010	50.00	59.73	65.65
2015	56.00	66.89	82.51

The SCC per tonne of carbon sequestered is multiplied by the physical supply units to determine the welfare value. There is a large range of modelled SCC in the relevant academic literature. The EPA SCC is a conservative estimate of SCC from 2010 to 2050. The estimates of SCC for 2010 and 2015 under a modelled scenario of 2.5% discount rate were applied in this analysis. We adopted the EPA discount rate of 2.5%, in line with the recommended discount rates for low-risk infrastructure from the Victorian government (*Economic Evaluation for Business Cases Technical Guidelines*, 2013). We note that this is lower than the +/- 7% recommended by the Australian Government for regulatory interventions (Office of Best Practice Regulation, 2020) however, this is an area of active debate in parliament (Deans, 2018). Additionally, this approach reflects the current view of environmental economic accounting, which encourages assets viewed over the long term to have lower discount rates. For completeness, the integrated accounts report incorporates discount rates of 4% and 7% in the ecosystem asset valuation as a sensitivity analysis (McLeod et al., 2021).

As with the exchange value, the SCC is applied to the carbon dioxide that the ecosystem can sequester to determine the welfare value. Tonnes of physical carbon supplied by the GKP ecosystem is converted to carbon dioxide equivalent units (CO_2e) using the Carbon to CO_2e factor (Table 32). The monetary value of carbon sequestration from the GKP ecosystem in 2010 and 2015 is the product of the associated exchange value and the CO_2e that the ecosystem sequesters. Total welfare value for the GKP ecosystem is presented in Table 32.

Table 32 EPA Social Cost of Carbon Value – Welfare Value

	Carbon	Carbon to Co2e factor	Average Global SCC ($AUD/t CO2e)	Total Welfare Value
2010	1,022,807	3.664	65.65	246,004,000
2015	1,030,771	3.664	82.51	311,605,000

Estimates

The total monetary supply of carbon sequestration calculated using the emissions reduction fund exchange value is presented in Table 27 and the World bank exchange value in Table 30. The total social cost of carbon sequestration, calculated using the EPA welfare value, is presented in Table 32. The same method used to calculate these total values was employed to calculate monetary supply and welfare value across the relevant GKP ecosystem types. The exchange value monetary supply in 2010 and 2015 is presented in the accounting output tables Table 36 and Table 37 respectively. The welfare values calculated across the ecosystem accounts are presented in Table 38.

4.5.3 Areas for improvement

Additional research can focus on improving the understanding of carbon sequestration and retention within the GKP ecosystem and the various ways these components of the global climate regulation service can be impacted. The influence that soil health and soil moisture has on carbon sequestration is a particular point of interest for future research. The carbon sequestration estimates included above and below ground living and dead biomass, but soil carbon was not included in the accounts and should be included in future iterations. Understanding these dependencies will contribute to improved AusEcoModel state and transition conceptual models.

Analysis of carbon sequestration within GKP relied on contemporary literature and modelling using FullCAM software. It is recognised FullCAM default values for GKP are lower than that identified through site based ecological monitoring programs. Additional information on vegetation characteristics that could be used to populate FullCAM at the site scale would help refine the estimates. Consideration of carbon losses from decay and succession processes would help with the accounts. Changes in ecosystem condition (2010 and 2015) are based on changes to ecosystem types. Areas identified as Inland eucalypt forest and woodland when inundated through natural or environmental watering events will be identified as wetlands. Carbon calculation in methods do not reliably account for this difference. This is an area for further work.

Carbon calculations for wetlands were based on average values (Carnell et al., 2018) taken from amalgamation of a state-wide survey of Victorian wetlands. Averages are highly variable and confirmation of values for GKP would require an extensive sampling program.

4.5.4 Accounting outputs

Carbon stock measures

In 2010 carbon stock in Gunbower forest varies across the landscape with an estimated 1,796,913 tonnes in Inland floodplain eucalypt forest and woodland, 87,774 tonnes in wetlands, 89,529 tonnes in Re-sprouter temperate and subtropical eucalypt woodlands and 3783 tonnes in Fire-intolerant *Callitris* woodland (Table 33). In Koondrook Perricoota carbon stock is higher with an estimated 3,011,656 tonnes in Inland floodplain eucalypt forest and woodland, 466,428 tonnes in wetlands, 83,663 in Re-sprouter temperate and subtropical eucalypt woodlands and 55,171 tonnes in Fire-intolerant *Callitris* woodland (Table 33).

In 2015, carbon stock in Gunbower ecosystem types was estimated at 1,943,499 tonnes for inland floodplain eucalypt forest and woodland, 89,698 tonnes in Re-sprouter temperate and subtropical eucalypt woodlands, 75,539 tonnes for wetlands and 3783 tonnes for Fire intolerant *Callitris* woodlands (Table 33). In Koondrook Perricoota ecosystem types, carbon stock was estimated at 2,919,186 tonnes for inland floodplain eucalypt forest and woodland, 558,872 tonnes for wetlands, 83,825 tonnes in Re-sprouter temperate and subtropical eucalypt woodlands, and 56,675 tonnes for Fire tolerant *Callitris* woodlands (Table 33).

Accumulation in carbon stock due to growth was assessed using FullCAM for the period 1990 to 2020. Modelling of carbon accumulation identified increased carbon stocks in Gunbower for Inland floodplain eucalypt forests and woodlands and Re-sprouter temperate and subtropical eucalypt woodlands (Table 34). Carbon stocks in Koondrook Perricoota increased between 2010 and 2015 for wetlands, Re-sprouter temperate and subtropical eucalypt woodlands, and Fire tolerant *Callitris* woodlands.

Reductions in carbon stock in Gunbower occurred only for wetlands reflecting a lower area of semi-permanent wet (low or moderate) condition wetlands. Decreases in carbon stock at Koondrook Perricoota primarily occurred for Inland floodplain eucalypt forests and woodlands. This reduction in part will be through timber and firewood harvesting in Koondrook Perricoota forestry compartments. While forest timber harvesting by area is relatively low (1-3% per annum 2010 and 2015) it does result in a reduction in sequestered and stored carbon. Incidence of fires as wildfire and prescribed burns is limited in recent history across the entire site and has not influenced carbon stocks.

FullCAM modelling of carbon stocks provided an estimate per hectare for each ecosystem type. Carbon stock estimates (per hectare for each ecosystem type) were similar between 2010 and 2015 (Table 33 and Table 34). Wetlands and Inland floodplain Eucalypt forests and woodlands with highest stocks of 648 and 517 tonnes C per hectare respectively.

Table 33 Carbon stock for each ecosystem type in 2010 and 2015.

		Ecosystem type											
		Gunbower						Koondrook - Perricoota					
	Units	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt	Lowland Streams
2010	tonnes C	3783	1,796,913	87774	9	89,529	-	55,171	3,011,656	466,428	4	83,663	-
2015	tonnes C	3783	1,943,499	75539	9	89,698	-	56,675	2,919,186	558,872	5	83,824	-
change	tonnes C	-	146,586	-12235	-	169	-	1,504	-9,2471	92,444	1	161	-

Note: '–' = 0 Changes in carbon stock for ecosystem types calculated

Table 34 Carbon stock and sequestration estimates (per Ha) for ecosystem types at GKP. Units stock carbon tonnes /Ha and sequestration tonne carbon /Ha/yr Terrestrial estimates from FullCAM and wetlands based on estimates from Carnell et al., (2018)

		Ecosystem type											
		Gunbower						Koondrook - Perricoota					
Ecosystem service	Units	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
Carbon stock	tonnes C/Ha	104	517	648	0.18	99	-	131	517	648	0.18	88	-
Carbon Sequestration	tonnes C/Ha/yr	20	104	6	0.20	20	-	19	105	6	0.20	18	-

Note: '–' = 0

Carbon sequestration physical supply and use

A carbon sequestration physical supply and use table for 2010 and 2015 (Table 35) and monetary supply and use tables for 2010 (Table 36) and 2015 (Table 37) were developed for the accounting area. The physical and monetary supply and use tables show the relationship between carbon sequestration supplied by the GKP ecosystem, and the exchange value provided to the government as the user. The welfare value analysis sits outside the environmental economic accounting framework and is presented separately from the supply and use tables (Table 38). Welfare values rely on the social cost of carbon, instead of the exchange value of carbon, and were calculated for 2010 and 2015.

In 2010 carbon sequestration in Gunbower Forest varies across the landscape with an estimated carbon sequestration of 363,912 tonnes in Inland floodplain eucalypt forest and woodland, 18,172 tonnes in Re-sprouter temperate and subtropical eucalypt woodlands, 711 tonnes in Fire tolerant *Callitris* woodlands and 563 tonnes in wetlands. Table 35. In Koondrook Perricoota carbon sequestration is higher with an estimated 611,370 tonnes in Inland floodplain eucalypt forest and woodland, 3,235 tonnes wetlands, 16,982 in Re-sprouter temperate and subtropical eucalypt woodlands (Table 35). The higher estimates reflect the greater area of Koondrook Perricoota.

In 2015, carbon sequestration in Gunbower ecosystem types was estimated at 392,019 tonnes for inland floodplain eucalypt forest and woodland, 18,150 tonnes in Re-sprouter temperate and subtropical eucalypt woodlands, 711 tonnes for Fire tolerant Callitris woodlands and 512 tonnes for wetlands. For Koondrook Perricoota ecosystem types, carbon sequestration was estimated at 590,676 tonnes for inland floodplain eucalypt forest and woodland, 16,962 tonnes in Re-sprouter temperate and subtropical eucalypt woodlands, 7,853 tonnes for Fire tolerant Callitris woodlands and 3,879 tonnes for wetlands.

Accumulation in carbon stock due to growth was assessed using FullCAM for the period 1990 to 2020. Modelling of carbon sequestration rates identified increased carbon stocks in Gunbower for Inland floodplain eucalypt forests and woodlands (Table 35). Carbon sequestration rates in Koondrook Perricoota increased between 2010 and 2015 for wetlands only.

Reductions in carbon sequestration rates in Gunbower occurred only for wetlands and Re-sprouter temperate and subtropical eucalypt woodlands reflecting a lower area of semi-permanent wet (low or moderate) condition wetlands. Decreases in carbon stock at Koondrook Perricoota primarily occurred for Inland floodplain eucalypt forests and woodlands. This reduction in part will be through timber and firewood harvesting in KP forestry compartments. While forest timber harvesting by area is relatively low (1-3% per annum 2010 and 2015) it does result in a reduction in sequestered and stored carbon.

Carbon sequestration monetary supply and use

Table 36 outlines the monetary supply and use calculated for carbon sequestration within the GKP ecosystem in 2010. The monetary supply and use calculations rely on the weighted average exchange value of all ACCUs traded within the Commonwealth's Emissions Reduction Fund and the median exchange value of carbon sequestration on international markets in 2010 as recorded on the World Bank Carbon Pricing Dashboard. The total monetary supply and use of carbon sequestration relying on ACCU exchange values was around 48 million. This is compared to the total monetary supply and use of carbon sequestration calculated using the World Bank Carbon Pricing median in 2010 which is around 70.1 million. 'Inland floodplain eucalypt forests and woodlands' supplied around 16.9 million and 28.5 million of monetary supply and use across Gunbower forest and Koondrook-Perricoota forest respectively in 2010 when calculations relied on ACCU exchange values. When calculations relied on the World Bank Exchange values the monetary supply from 'Inland floodplain eucalypt forests and woodlands' was around 25.1 million and 42.1 million from Gunbower and Koondrook-Perricoota forests respectively.

Table 37 outlines the monetary supply and use calculated for carbon sequestration within the GKP ecosystem in 2015. The monetary supply and use calculations rely on the weighted average exchange value of ACCUs traded within the Commonwealth's Emissions Reduction Fund in 2015 and the median exchange value of carbon sequestration on international markets in 2015 as recorded on the World Bank Carbon Pricing Dashboard. The total monetary supply and use of carbon sequestration relying on ACCU exchange values was around 49.4 million. This is compared to the total monetary supply and use of carbon sequestration calculated using the World Bank Carbon Pricing median in 2015 which is around 93.5 million. 'Inland floodplain eucalypt forests and woodlands' supplied around 18.8 million and 28.3 million of monetary supply and use across Gunbower forest and Koondrook Perricoota forest respectively in 2015 when calculations relied on ACCU exchange values. When calculations relied on the World Bank Exchange values the monetary supply from 'Inland floodplain eucalypt forests and woodlands' was around 35.5 million and 53.6 million from Gunbower and Koondrook Perricoota forests respectively.

Table 38 outlines the welfare value of carbon sequestration and sits outside the traditional System of Environmental Economic Accounting (SEEA) framework. The welfare value is presented in this analysis as a comparison to the exchange values in the monetary supply and use table for carbon sequestration (Table 38) and are valued using the social cost of carbon (SCC) calculated by the US EPA (2016). The SCC represents the economic value of the damage caused by the emission of a marginal tonne of carbon into the atmosphere. In 2010 the total welfare value of carbon sequestration from the GKP ecosystem was around 246 million. In 2015 this total is estimated at around 311 million. 'Inland floodplain eucalypt forests and woodlands' supplied around 87 million and 147 million of welfare value across Gunbower forest and Koondrook Perricoota forest respectively in 2010. In 2015 the welfare value supplied by the 'Inland floodplain eucalypt forests and woodlands' rose to around 118 million and 178 million from the Gunbower forest and Koondrook Perricoota forest, respectively.

Table 35 Carbon sequestration physical supply and use table, GKP, 2010 and 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply /Use	Units	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
2010																
Supply	tonnes				711	363,912	563	5	18,172	0	7,854	611,370	3,235	4	16,982	0
Use	tonnes	-	1,022,807	-												
2015																
Supply	tonnes				711	392,019	512	5	18,150	0	7,853	590,676	3,879	5	16,962	0
Use	tonnes	-	1,030,771	-												

Note: Physical supply and use of Carbon sequestration is based on 2010 and 2015 data. Yields data was measured in tonnes of carbon for each ecosystem type. Confidence in data is high. Yield data was provided by CSIRO and complemented by FullCAM modelling. Estimates can be improved with a better understanding of the ecological system and how it sequesters carbon as a whole, especially the contribution of soil. '–' = 0

Source: Data from FullCAM calculated sequestration and stock values and wetland estimates based on Carnell et al (2018)

Table 36 Carbon sequestration monetary supply and use summary table, GKP, 2010

			Economic units			Ecosystem type											
						Gunbower						Koondrook - Perricoota					
Supply/ Use	Units	Source	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
Supply	$ AUD	ACCUs				33,000	16,961,000	26,000	-	847,000	-	366,000	28,495,000	151,000	-	791,000	-
Use	$ AUD	ACCUs		47,670,000													
Supply	$ AUD	WBM				49,000	25,094,000	39,000	-	1,253,000	-	542,000	42,158,000	223,000	-	1,171,000	-
Use	$ AUD	WBM		70,529,000													

Note: Monetary supply and use from carbon sequestration in 2010 is derived from the average 2010 ACCUs sale price in the Commonwealth's Emissions Reduction Fund and the median price (WBM = World Bank Median) of carbon from international markets in 2010, as reported on the World Bank Carbon Pricing Dashboard. The monetary supply and use of carbon sequestration is presented in nominal terms. Confidence in estimates is medium. Yield values from the GKP ecosystem include some uncertainty and are a function of the best available information involved in FullCAM yield modelling. '–' = 0

Source: Data from (FullCAM carbon estimates based on estimates based on Carnell et al (2018), ACCU exchange values rely on the Commonwealth's Emissions Reduction Fund sale prices of Australian Carbon Credit Units (ACCUs).

Table 37 Carbon sequestration monetary supply and use summary table, GKP, 2015

			Economic units			Ecosystem type											
						Gunbower						Koondrook - Perricoota					
Supply/ Use	Units	Source	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
Supply	$ AUD	ACCUs				34,000	18,816,000	25,000	-	871,000	-	377,000	28,352,000	186,000	-	814,100	-
Use	$ AUD	ACCUs	49,475,000														
Supply	$ AUD	WBM				64,000	35,562,000	46,000	-	1,646,000	-	712,000	53,583,000	352,000	-	1,539,000	-
Use	$ AUD	WBM	93,504,000														

Note: Monetary supply and use from carbon sequestration in 2015 is derived from the average 2015 ACCUs sale price in the Commonwealth's Emissions Reduction Fund and the median price (WBM = World Bank Median) of carbon from international markets in 2015, as reported on the World Bank Carbon Pricing Dashboard. The monetary supply and use of carbon sequestration is presented in nominal terms. Confidence in estimates is medium. Yield values from the GKP ecosystem include some uncertainty and are a function of the best available information involved in FullCAM yield modelling. '–' = 0

Source: Data from (Terrestrial vegetation estimates from FullCAM and wetland estimates based on average stock and sequestration rates in Carnell et al (2018), ACCU exchange values rely on the Commonwealth's Emissions Reduction Fund sale prices of Australian Carbon Credit Units (ACCUs).

Table 38 Carbon sequestration welfare value, GKP, 2010 and 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply/ Use	Units	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
2010																
Supply	$ AUD				171,000	87,528,000	135,000	1,000	4,371,000	-	1,889,000	147,046,000	778,000	1,000	4,084,000	-
Use	$ AUD	-	246,004,000	-												
2015																
Supply	$ AUD				215,000	118,508,000	155,000	1,000	5,487,000	-	2,374,000	178,563,000	1,173,000	1,000	5,128,000	-
Use	$ AUD	-	311,605,000	-												

Note: The welfare value of carbon sequestration in 2010 and 2015 is derived from the average United States Environmental Protection Agency (EPA) estimates of the global social cost of carbon sequestration in target years. Welfare value estimates were derived by the EPA in 2016 and are conservative. Updated modelling of welfare value estimates including contemporary assumptions would be useful for future analysis. Updated modelling could include market and non-market impacts from environmental tipping points. The welfare values of supply and use of carbon sequestration are presented in nominal terms. Confidence in estimates is medium. Yield values from the GKP ecosystem include some uncertainty and are a function of the best available information involved in FullCAM yield modelling. '–' = 0

Source: Data from (Terrestrial vegetation estimates from FullCAM and wetland estimates based on average stock and sequestration rates in Carnell et al (2018), welfare value calculations rely on (Interagency Working Group on the Social Cost of Greenhouse Gases 2016).

4.6 Floral resources for hive building

The GKP ecosystem provides floral resources as a service, which apiarists use to build the health and food stores of their hives. Healthy, well-stocked hives provide crop pollination services across Victoria and NSW, contributing to an Australia-wide industry that was estimated to return 40 million in revenue in 2019 (Clarke & Le Feuvre, 2021). The extent that the GKP ecosystem supports crop pollination as a service is difficult to quantify directly without an accurate understanding of how many trips apiarists took to the Gunbower, Perricoota and Koondrook forests to build or rest their hives in the target years. Instead, the qualitative value of the GKP ecosystem to the apiary industry is discussed. The direct users of this ecosystem service are local Victorian and NSW apiarists who place hives in the GKP ecosystem. Apiarists benefit from any improvement in the degree of ecological integrity of the forest that increases abundance or duration of flowering events and therefore increases the health of their colonies and the food stores within their hives. Figure 21 shows the relationship between the ecosystem service and humans.

The main transaction of interest in this context is the relationship between the GKP ecosystem and apiarists. The GKP ecosystem provides floral resources for hive building as a biotic asset. Access rights to use this biotic asset are allocated by the government (in the form of accessible sites to place hives) which are reflected in the ecosystem services step as 'site rental' (Figure 21).

Apiary is a migratory industry and apiarists plan their hive placement 18 months in advance based on rainfall and environmental watering and flooding events. Hives are placed when the floral resources in the surrounding forest (flowering events) are sufficient. Floral resources in the GKP ecosystem are predominately provided by River red gum and Black Box eucalypts. *Eucalyptus camaldulensis* (River red gum) typically have a large flowering event every two years. Consultation with local beekeepers suggest that River red gums in the GKP ecosystem sustained a two-year flowering pattern up until the year 2000. Local beekeepers report that flowering events have not been as large or regular in Gunbower, Koondrook or Perricoota forests since 2000. Flowering events large enough to produce honey did not occur in 2010 or 2015.

Intermediate services flowering events

	Red gum	Black Box
Flowering frequency (years)	2 (1-8)	2 (1-5)
Flowering period	Summer	Depending on the location flowers observed in all months except February and March during 2004-2006 on the lower Murray floodplain (Jensen et al. 2008a). (response to water availability)
Nectar production quantity (tins) (~27kg per tin)	0.5-3.0	0.5-2.0
Nectar production frequency (years)	2-11+	1-10
Age of reproductive maturity (flowering)	20-40yrs	20-50yrs

Red gum and black box species commence flowering when they are between 20-50 years old. Maturation (and reproductive output) is influenced by interactions with existing vegetation and may be delayed until natural thinning of pole stage Eucalypts and suppression of weaker or smaller trees has occurred (Smith, 2001);(George, 2005). Tree condition also impacts reproductive output, with healthy trees producing more fruit and shedding larger quantities of seed than those with lower canopy vigour (George, 2005). Maximum bud loads (and flowers) are a likely result from their being sufficient water available to support reproduction. Once trees are mature, buds may be retained for up to 12 months before flowering. Under conditions of low rainfall and drought, buds may drop prior to flowering as a strategy to maintain tree health.

Water availability is a critical driver for flowering to occur. Sufficient water in the prior 12 months is the primary driver as flowering itself is relatively independent of rainfall (George, 2004), (Jensen, 2006). The number of flower buds is affected by water availability (170% increase recorded at one site following a high rainfall period (Jensen, 2006; Jensen et al., 2008). Both river red gum and Black Box trees primarily source water from groundwater, then surface water, then rainfall.

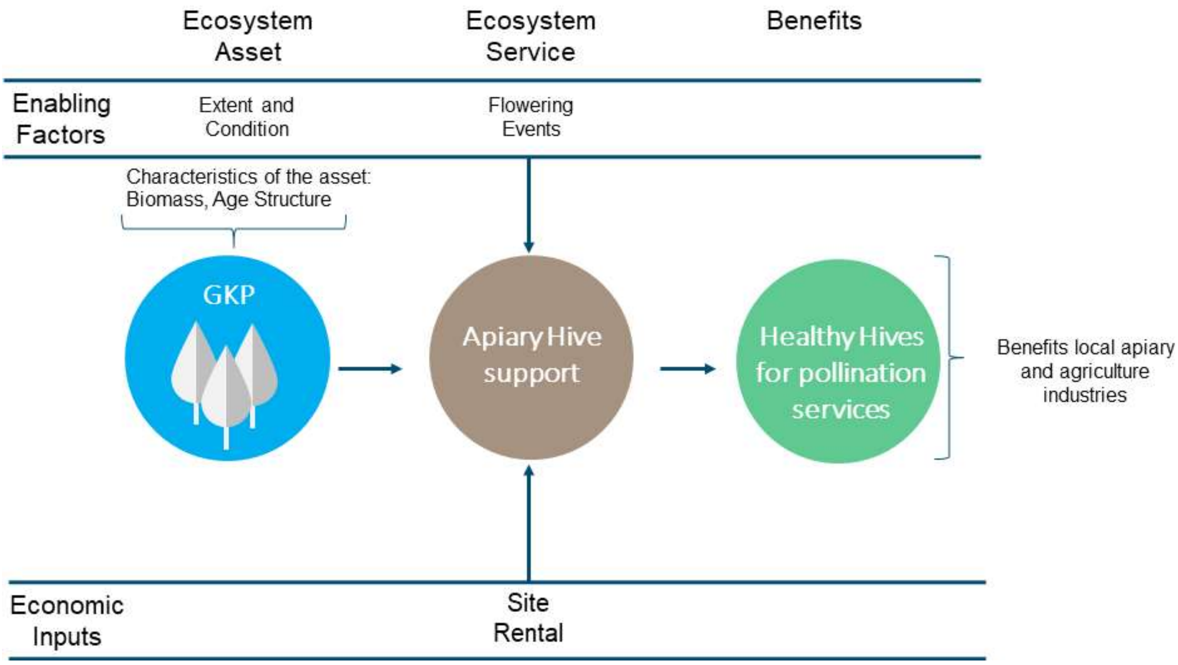
The correct environmental conditions will prompt large scale flowering events involving a majority of the red gum or black box community. Minor flowering events, involving individual trees, still occur under less favourable conditions. These smaller flowering events in the GKP ecosystem are still an important service for the apiary industry and allow apiarists to build the health of their hives. Apiarists transfer their hives over large distances to provide crop pollination services and pursue flowering events for honey production. In the absence of flowering events with large enough floral resources to produce honey, and if there are no crops to pollinate, the hives are rested. Apiarists rest hives in strategic locations to take advantage of minor floral resources in the surrounding ecosystem and continue building the health and food stores of their colonies. While local beekeepers report that flowering events large enough to produce honey did not occur in the GKP forests in 2010 or 2015, a proportion of apiarists surveyed still rested their hives on sites within Gunbower of Koondrook Perricoota forest.

There are other relationships that are not captured explicitly in Figure 21 but are important to consider. *Eucalyptus camaldulensis* (River red gum) forests are highly regarded for their ability to support and sustain bee hives. River red gums are well known in the apiary industry for producing high quality pollen. The quality of pollen is important for bee health, longevity and productivity. Hives that are healthy and well stocked with pollen are necessary when providing crop pollinating services.

Management and use of the GKP ecosystem for biomass for timber, firewood and recreation all act as potential additional pressures on the apiary industry. Tree harvesting reduces the supply of floral resources available and management burns disrupt hive placements. The link between the ecosystem (quantity and quality), the biomass (quantity and quality), and the transactions are key components of the narrative. The quantity and quality of the assets can affect the quantity of all transactions both now and into the future.

A complete information set will capture each activity or transaction, estimate the potential value of those transactions, and link them to an ecosystem asset to understand how the attributes and condition of the ecosystem affects the transaction. Stakeholders including government jurisdictions can contribute to the set of information outlined in Figure 21 to support the ongoing management of the GKP ecosystem.

Figure 21 Floral resources for hive building



4.6.1 Literature review

The calculation of monetary supply and use for provision of pollination services has predominately been undertaken at a state level. The migratory nature of the pollination industry makes a state-wide assessment of exchange values much more applicable than an approach focused on an individual site. Methods for monetary supply and use for pollination as an intermediary good based on exchange values have used a range of methods, not all consistent with the residual rents approach (Figure 3). A collection of the approaches taken to analyse the value of pollination services in Australia is outlined below:

- DELWP, Victorian Forests (2019): Used a residual rents approach to estimate the value of pollination services (The State of Victoria Department of Environment Land Water and Planning, 2019)
- NCEconomics, Environmental Watering Victoria (2020): Used a residual rents approach to estimate the value of pollination services (NCEconomics, 2020)
- ANU, Central Highlands (2016): Discussed measuring the exchange value of pollination services but detailed analysis was outside the scope of work (Keith et al., 2016)
- CSIRO, Green Triangle (2020): did not measure the exchange value of pollination services (Stewart et al., 2020)
- IDEEA, Forico (2018): did not measure the exchange value of pollination services (IDEEA Group, 2018)

4.6.2 Method

The GKP ecosystem contributes floral resources to the Victorian and NSW apiary industry as a service. Apiarists rely on these floral resources to build the food stores of their hives before providing crop pollination services. The value of the GKP ecosystem to crop pollination can be discussed in terms of the number of pollinators it supports, the quality of the support it provides and the economic value of the pollination services it enables. The migratory nature of the apiary industry means that all floral resources available across NSW and VIC are important for the provision of crop pollination services. This analysis discusses the crop pollination industry in Victoria and NSW as a whole, instead of attempting to attribute a share of the industry to the GKP ecosystem.

Floral resources provided by the GKP ecosystem have the potential to support a substantial proportion of Australia's crop pollination industry. Importantly, the GKP ecosystem is located on the border of NSW and Victoria, which are both key states for apiary in Australia. The majority of Australia's beekeepers and beehives are located in NSW and Victoria. 60% of Australia's beekeepers and 63% of Australia's beehives were based across NSW and Victoria in 2019 (Clarke & Le Feuvre, 2021). As a result, a significant proportion of Australia's commercial crop pollination services are provided across NSW and Victoria. In 2015, the Australian pollination industry consisted of an estimated 520,000 hives and returned around 24.9 million to recreational and commercial beekeepers. Of these 520,000 hives, around 30% were available for pollination services in Victoria and 40% were available in NSW (Clarke & Le Feuvre, 2021).

The GKP ecosystem provides high quality floral resources to support the crop pollination industry. The GKP ecosystem consists of large *Eucalyptus camaldulensis* (River red gum) forests that are highly regarded for their ability to support and sustain beehives. River red gums produce high quality pollen important for bee health, longevity and productivity. Hives that are healthy and well stocked with pollen are necessary when providing crop pollinating services. Different crops provide different amounts of sustenance to the bee colony (source). If apiarists are pollinating crops that provide the bees with minor amounts of pollen, the existing food stores within the hives must sustain the colony. This reinforces the importance of resting hives in ecosystems that can provide high quality food stores to the colony to support them in the future. Healthy, well-stocked hives provide crop pollination services without the need for supplementary feeding from apiarists. This reduces the market and non-market costs borne by the Apiary industry.

To the extent that the GKP ecosystem supports the crop pollination industry in Victoria and NSW, it is likely to provide significant value to the economy. Several studies have analysed the economic value of the Australian honeybee pollinating industry. It is estimated that in 2015 the Australian pollination industry provided around 14 billion of economic value by supporting the production of key fruit and vegetable agriculture. An average of 6.1 billion of the total economic value originated from pollination in Victoria and 2.5 billion from NSW (Krasinski, 2018).

4.6.3 Areas for improvement

A limitation of the analysis above is that recreational apiarists and commercial apiarists with less than 50 hives were not included in the analysis of Australia's pollination industry. This means estimates of commercial and recreational pollinator numbers across Australia are likely understated. Similarly, it is understood that apiarists often register their hives in multiple states because of the migratory nature of the industry. This means some hives are likely to be double counted.

Additional research should focus on improving the central collection and open access to apiary data across NSW and Victoria. This could allow future analysis to attribute a portion of the crop pollination industry to the GKP ecosystem. We understand that Forestry Corp NSW is in the process of registering all beekeepers and their hives online, in an attempt to record how they utilise forest ecosystems. This information, and information from a similar system in Victoria, would significantly enhance the power of future analysis.

4.7 Ecosystem and species appreciation

The GKP ecosystem provides habitat for a wide range of species (including birds, mammals, fish, frogs and reptiles) that support flows of non-use values to people. These flows are treated as complementary valuations within the SEEA EA. Complementary values are defined as a flow related to non-use values, in this case, the flow is ecosystem and species appreciation. It is important to note that ecosystem and species appreciation has been presented here as an exchange value, where the SEEA standard exclusively discusses non-use values as welfare values. As the exchange value of ecosystem and species appreciation value is non-use, it is considered separately to the other exchange values presented in this report.

Flows have been quantified as the area of habitat for 8 focal species that are listed as species of national environmental significance under the *Environment Protection and Biodiversity Conservation Act 1999* and in the Ecological Character Description for Gunbower and Koondrook Perricoota Ramsar sites. The 8 focal species include Australasian bittern, painted honeyeater, superb parrot, growling grass frog, koala, rigid spider-orchid, winged pepper-cress, river swamp wallaby-grass within the boundaries of GKP.

It is important to emphasise that the 8 focal species are a subset of the total number of species in GKP. This means the accounting estimates presented in this section only relate to the subset of eight focal species. The direct user of the flows from these eight focal species are Australian households; however, as endemic and endangered Australian species, the beneficiary population could extend beyond local communities and Australian households. People overseas may place a non-use value on Australia's native wildlife.

Data about these species is also relevant in managing and conserving the GKP ecosystems. Maintaining habitat is essential for species during their breeding or non-breeding season. Inclusion of habitat in management priorities for species protection is recognised as a critical component for persistence of species (Brundrett, 2016; Mott et al., 2020).

Figure 22 shows the relationship between ecosystem and species appreciation and benefits for the eight focal species (as a subset of all species) within the boundaries of GKP.

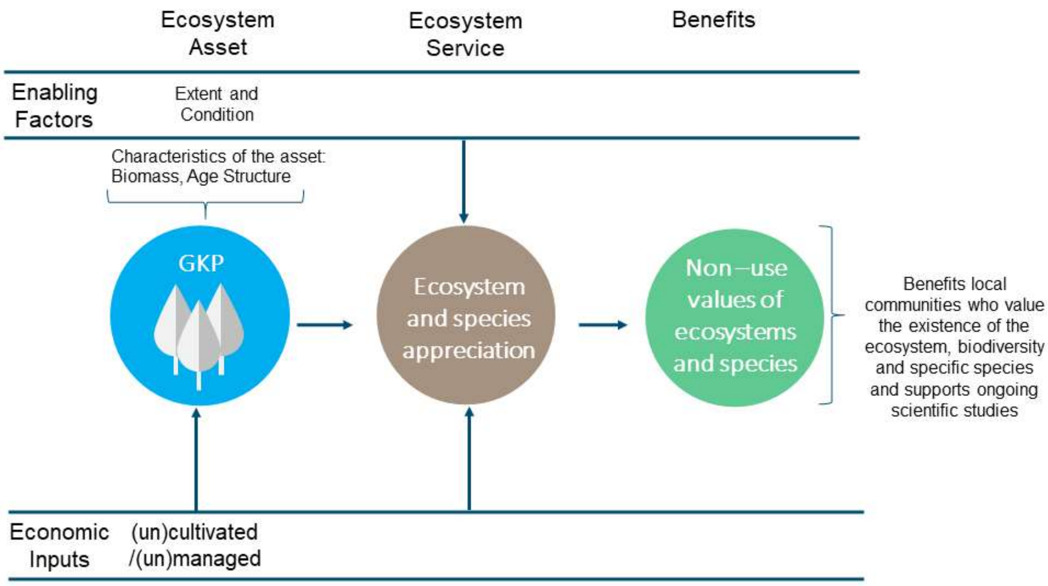
Habitat for the eight focal species has been identified drawing on the CSIRO species-level biodiversity assessments (see Chapter 9 (McLeod et al 2021) and Mokany et al. 2021a,b). The biodiversity assessment used estimates of the original spatial distribution for each focal species from the Species of National Environmental Significance database (Mokany et al 2021a). Suitable habitat for focal species was determined spatially by allocating land cover attributes representative of their broad habitat preference (Mokany et al 2021a).

Presence of suitable habitat based on the CSIRO modelling indicates the habitat is considered suitable to support the focal species. It does not indicate these species are actually present. As such, the accounting estimates for species are based on habtat proxies. The proxy approach based on habitat hectares was used in the GKP because data on species abundance and distribution in GKP was not available.

There are other relationships that are not captured explicitly in Figure 22 but are important to consider in site management. The suitability of habitat is likely to be influenced by natural and endogenous events. The ecosystem services provided by habitat are also likely to benefit other species or contribute to user experience (for example, camping). More broadly biodiversity at GKP is a critical asset for maintaining the capacity of ecosystems and ecosystem complexes to deliver goods and services into the future (King et al., 2019). The link between the ecosystem (extent and condition) and habitat reflects the underlying capacity of the system to continue to support ecosystem and species appreciation supply.

A complete information set will capture each activity or transaction, estimate the value of those transactions, and link them to an ecosystem asset to understand how the attributes and condition of the ecosystem affects the transaction. Stakeholders, including government jurisdictions can contribute to the set of information outlined in Figure 22 to support the ongoing management of the GKP ecosystem.

Figure 22 Ecosystem and species appreciation – 8 focal species



4.7.1 Literature review

Two approaches are mainly used to value ecosystem habitat – nursery and species preservation for appreciation. These approaches are discussed below.

Nursery

The nursery service is generally valued by starting from the market price of the mature, harvested species and deducting relevant costs, consistent with the residual rent approach (Figure 3). This is relatively uncontroversial in terms of a valuation method. Note that in the context of GKP, many of the species are not harvested for commercial markets. The nursery approach therefore has potentially limited coverage.

Species preservation

Species preservation can be valued in a variety of ways (IDEEA Group, 2018):

- Stated preference values for individual species based on surveys of individuals' willingness to pay to protect and preserve certain species.

Several studies have attempted to value species, habitat and / or species abundance in the southern Murray-Darling basin, through a mix of value transfer (Morrison & Hatton-MacDonald, 2010) and primary revealed (Tapsuwan et al., 2015) stated preference study based valuation (Gunawardena et al., 2020a; MacDonald et al., 2011). Of these studies, the recent work valuing multiple threatened species and ecological communities in Australia (Gunawardena et al., 2020a) provides the most contemporary estimates. We note here that (1) only a small number of protected species relevant to the GKP are included in this study – for example Murray cod, and the Australasian Bittern. This means using values from this study would only provide a partial coverage of welfare values from users (2) the study has limitations with respect to scale, scope, and other effects. These can be adjusted to provide robust value transfer estimates.

- Values from biodiversity markets where prices are paid to retain habitat types using economic instruments (including offset markets and reverse price auctions) where the intent is to protect and preserve certain species and/or maintain biodiversity. A related approach is to consider the nature of conservation covenants and the extent to which there are any economic benefits flowing to covenant holders that would reflect the value of habitat services.

Our review of the Victoria Native Vegetation Credit Register traded credits information database and the NSW biodiversity spot price index and underlying datasets highlights that there is limited species offset price data available. This means habitat hectares needed to be used, with inference made for the hectares needed to support species valued by users. This is an indirect proxy method for approximately valuing the 8 focal species.

4.7.2 Method

Physical and monetary flows of ecosystem and species appreciation were produced in this analysis. A focus was to integrate the account ready biodiversity data outlined elsewhere in this report. Detailed methods for calculating the physical and monetary supply are outlined below. All datasets relied on for the analysis of these flows are referenced at the bottom of the account tables.

Physical flow accounts – Ecosystem and species appreciation

Method

The physical flow accounts for ecosystem and species appreciation for the 8 focal species records the supply of these flows. The estimation of physical flow accounts for habitat involved:

Spatial assessment in GKP identified for 2010 and 2015 the likely extent of suitable habitat for the 8 focal species (Mokany et al., 2021).

Ecosystem service characteristics are defined based on assessed areas of habitat in GKP for 8 focal species. CSIRO biodiversity data provided individual data sets for 10 focal species. The assessment process identified areas of suitable habitat (ecosystem types) in 2010 and 2015 for the 10 focal species as a subset of all species at GKP. The assessment does not indicate presence of these species only suitable habitat. Defining the areas of suitable habitat supporting two or more focal species is a proxy that aligns with habitat hectares. Habitat hectares was used in the GKP because data on species abundance and distribution was not readily available from the CSIRO work. Additionally, this analysis excludes two of the focal species included in the CSIRO work, Black Box and River Red Gum, because they are highly abundant across the GKP area. Inclusion of Black Box and River Red Gum species in the analysis would have skewed results.

Spatial data for areas of suitable habitat in 2010 and 2015 showed some variability. To quantify the ecosystem service for habitat, spatial analysis of suitable habitat for the 8 focal species was conducted using a spatial mosaic analysis that identified cells that provided persistent habitat for two or more species. This analysis categorised cells (normalised score) for habitat. Spatial results were presented for 2010 and 2015.

Based on the assessment of suitable habitat across all focal species, areas of ecosystem types were calculated to quantify the area of ecosystem habitat that contributes to moral wellbeing and knowledge of the environment in GKP. The physical supply of habitat hectares was also developed to quantify the habitat values for monetary valuation. This reflects a habitat valuation approach analogous to habitat hectares. The spatial area included all ecosystem types across GKP.

Estimates

Estimates of areas of habitat (ecosystem type) expected to provide suitable habitat for the 8 focal species is presented in Table 39 and Table 40. Change in areas are mapped in Figure 23 and Figure 24.

Table 39 Estimates of total area by ecosystem type expected to support 8 focal species for 2010

	Ecosystem type											
	Gunbower						Koondrook - Perricoota					
Ecosystem service	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
Supply												
Suitable habitat No. Focal species												
Eight focal species		10	3		1	1		148	108		2	
Seven focal species								54				1
Six focal species		2	2					1	1			
Five focal species	3	13,939	372	3	762	52	70	19,753	2,927		810	45
Four focal species	4	1,457	46	1		5	8	2,942	597			2
Three focal species		348	36	1	2	12	1	217	48		2	12

Two focal species								1				
Total Area	7	15,756	459	5	765	70	79	23,116	3,681	0	814	60

Table 40 Estimates of total area by ecosystem type expected to support 8 focal species for 2015

	Ecosystem type											
	Gunbower						Koondrook - Perricoota					
Ecosystem service	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
Supply												
Suitable habitat No. Focal species												
Eight focal species		12	3					103	148		2	
Seven focal species								54				
Six focal species		1						1				
Five focal species	2	11,504	332	6	633	60	20	10,342	2,374		558	36
Four focal species	3	1,176	45	2	1	6		608	265			
Three focal species		134	9	1	2	6		99	42		2	5
Two focal species												
Total Area	5	12,827	389	9	636	72	20	11,207	2,829	0	562	41

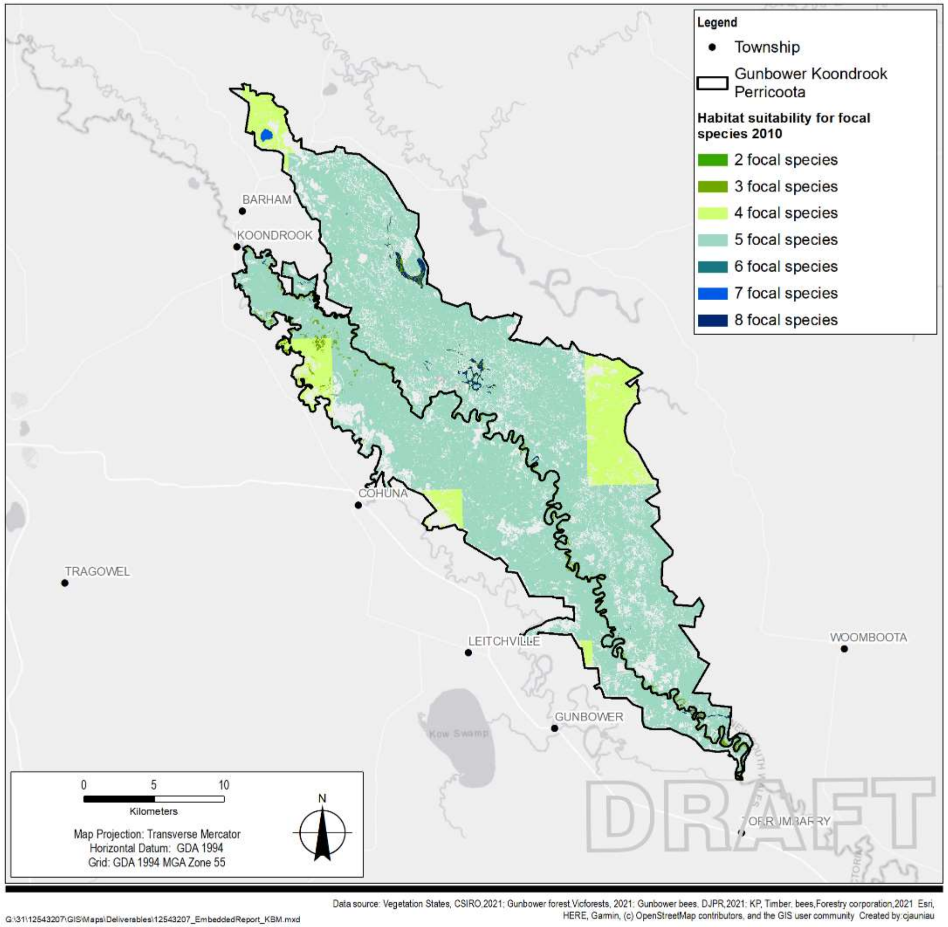


Figure 23 Areas in GKP identified to provide suitable habitat in 2010 for up to 8 of the focal species

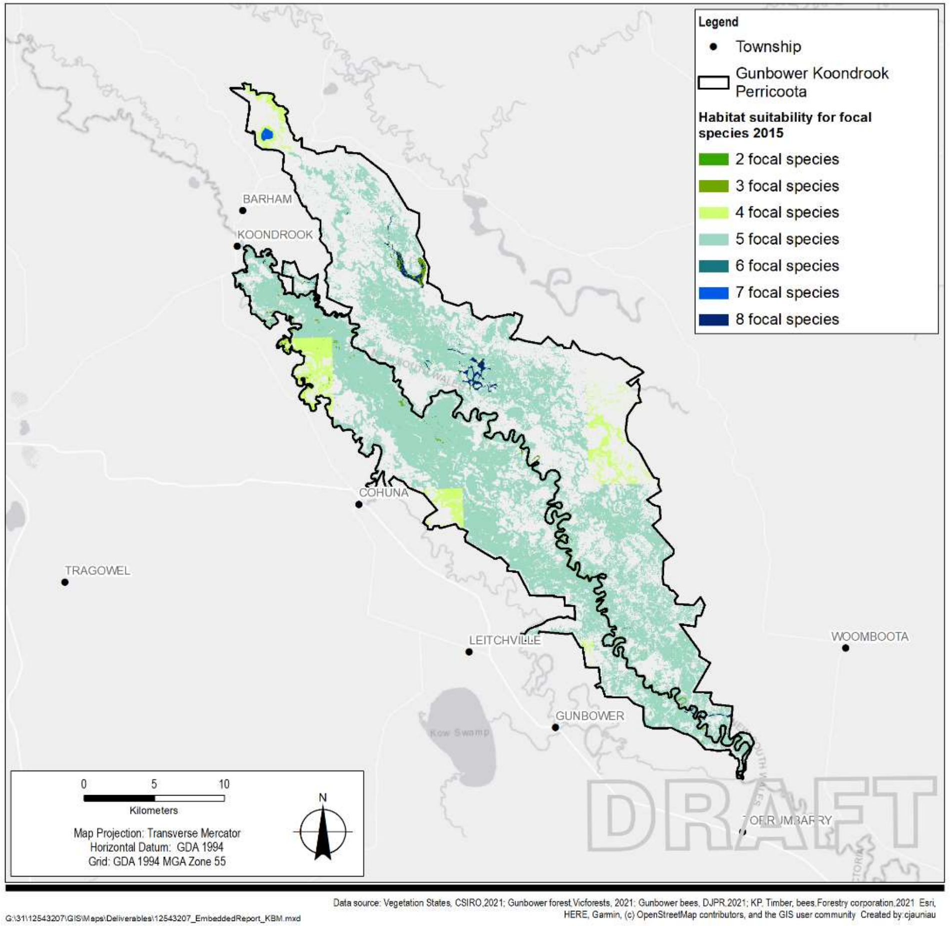


Figure 24 Areas in GKP identified to provide suitable habitat in 2015 for up to 8 of the focal species

Monetary ecosystem service accounts – Ecosystem and species appreciation

Method – Valuing the 8 focal species

The monetary ecosystem accounts for ecosystem species and appreciation calculate the exchange value of the non-use values of ecosystems and species provided in 2010 and 2015 respectively for the 8 focal species. This relationship is represented by:

$$\$ES_{s,y,i,t,wm} = \sum_{s,y,i,t} \left(H_{s,y,i,t} * P_{s,y,i,t,}\right)$$

,

Where:

$\$ES_{s,y,i,t,wm}$ is the non-use value of ecosystems and species, measured as the value of the habitat required to support a species (s), in year (y), at geographic location (i), ecosystem type (t), measured using observed biodiversity offset market trades

$H_{s,y,i,t}$ is the habitat in hectares required to support (s) in year (y) from location (i), ecosystem type (t)

$P_{s,y,i,t,}$ is the annuity equivalent biodiversity market price for habitat hectares in year (y) from location (i), ecosystem type (t). The annuity price converts the capitalised offset price into annual payments to be consistent with the annual accounting stance for ecosystem service supply.

$\sum_{s,y,i,t}$ shows that the total value is the sum of total hectare payment requirements for the 8 focal species.

A general description of how the monetary ecosystem accounts for habitat were produced is outlined below:

The value to households of habitat supplied by the GKP ecosystem was interrogated. This is summarised as habitable hectares within the Gunbower ecosystem as well as the Koondrook-Perricoota ecosystem. Habitable hectares supplied by the GKP ecosystem for each ecological vegetation class was based on the quality of the vegetation class in the vegetation class. Estimates were developed using EnSym and are summarised for Gunbower and Koondrook-Perricoota in Table 41 below:

Table 41 Habitable hectares physical supply - for 8 focal species

			Ecosystem		
Habitat hectares	Year	Unit	Gunbower	Koondrook-Perricoota	Total
Supply	2010	Ha	20,983	34,816	55,799
Supply	2015	Ha	20,986	34,819	55,805

The exchange value approach was used to value habitat within the GKP ecosystem. There are a variety of exchange values available for habitat hectares for biodiversity conservation. For Victoria, The Victorian Native Vegetation Credit Trade Register (DELWP, 2021b) was interrogated to calculate volume weighted average prices (VWAP) for Habitat Hectares[1] ($VWAPHH), by ecological vegetation class (EVC) for offsets registered in 2010 and 2015 respectively. The Victorian VWAP for Habitat Hectares, by ecological vegetation class (EVC) for offsets registered in 2010 and 2015 respectively was also used to establish exchange values for NSW habitat because the NSW biodiversity credit transactions and sales register (NSW Department of Planning) reports credits and prices but not hectares in the register.

The VWAP was found for the closest equivalent vegetation classes (EVC) traded on the exchange. The vegetation classes equivalent to the ecosystem types in the GKP ecosystem were identified using DELWP's Naturekit map (DELWP, 2020). Where the equivalent EVC was not traded on the exchange in high enough numbers to determine an accurate VWAP, a similar EVC that had been traded was identified using EVC benchmarks for the Murray Fans bioregion (DELWP, 2021a).

EVC's that are similar to the ecosystem types, but not equivalent, are the "Creekline Grassy Woodland" and "Riverine Chenopod Woodland". Both EVC have lower percentage canopy density for River Red Gum's than the original EVC. The trade price of EVC on the Victorian Native Vegetation Credit Trade Register takes this into account and it is likely that the price of these similar EVCs is lower than what the Riverine Swamp Forest and Grassy Riverine Forest would be if they were traded. The estimates produced are likely conservative as a result. The EVC adopted for this analysis and their relationship with the different ecosystem types is demonstrated in Table 42.

Ecological Vegetation classes were not identified for cultivated areas or lowland streams. Neither Cultivated area (agricultural land) nor lowland streams (aquatic systems) are traded on the Victorian Native Vegetation Credit Trade Register and were not valued as habitable ecosystem in this analysis.

Table 42 Adopted Ecological Vegetation Class

GKP Ecosystem Type	Ecological Vegetation Class	EVC #	Adopted Ecological Vegetation Class	EVC #
Fire-intolerant Callitris woodlands	Riverine Swamp Forest	814	Creekline Grassy Woodland	68
Inland floodplain eucalypt forests and woodlands	Grassy Riverine forest	106	Riverine Chenopod Woodland	103
Wetlands	Spike-Sedge Wetland	819	Spike-Sedge Wetland	819
Cultivated areas	-	-	-	-
Re-sprouter temperate and subtropical eucalypt woodlands	Plains Woodland	803	Plains Woodland	803

[1] Habitat hectares are a combined measure of condition and extent of native vegetation (DELWP. (2021b). Native Vegetation Credit Register. In.)

GKP Ecosystem Type	Ecological Vegetation Class	EVC #	Adopted Ecological Vegetation Class	EVC #
Lowland Streams	-	-	-	-

The $VWAPHH for each GKP ecosystem type is presented in Table 43. When there were not enough transactions in 2010 and 2015, transactions in surrounding years were included to build a more robust weighted average price calculation.

Table 43 Volume weighted average prices

GKP Ecosystem Type	Ecological Vegetation Class	Volume Weighted average price per habitable hectare	
		2010	2015
Fire-intolerant Callitris woodlands	Creekline Grassy Woodland	143,231	158,736
Inland floodplain eucalypt forests and woodlands	Riverine Chenopod Woodland	91,405	59,545
Wetlands	Spike-Sedge Wetland	213,223	206,149
Cultivated areas	-	-	-
Re-sprouter temperate and subtropical eucalypt woodlands	Plains Woodland	50,791	64,160
Lowland Streams	-	-	-

The capital value of each ecosystem service was calculated as the product of the weighted average price of each equivalent ecosystem type and the physical supply of the ecosystem (Table 44).

Table 44 Capital Value Calculation

Ecosystem Type	Ecological Vegetation Class	Volume Weighted average price/ HH		Habitat Supply (Ha)		Capital value ($AUD)	
		2010	2015	2010	2015	2010	2015
Gunbower							
Fire-intolerant Callitris woodlands	Creekline Grassy Woodland	143,231	158,736	36	36	5,218,971	5,783,930
Inland floodplain eucalypt forests and woodlands	Riverine Chenopod Woodland	91,405	59,545	18,632	18,719	1,703,015,582	1,114,609,034
Wetlands	Sedge Wetland	213,223	206,149	523	450	111,595,661	92,664,053
Cultivated areas	-	-	-	309	323	-	-
Re-sprouter temperate and subtropical eucalypt woodlands	Plains Woodland	50,791	64,160	902	902	45,801,115	57,856,556

Ecosystem Type	Ecological Vegetation Class	Volume Weighted average price/ HH		Habitat Supply (Ha)		Capital value ($AUD)	
		2010	2015	2010	2015	2010	2015
Lowland Streams	-	-	-	580	556	-	-
Koondrook-Perricoota							
Fire-intolerant Callitris woodlands	Creekline Grassy Woodland	143,231	158,736	421	421	60,228,538	66,748,333
Inland floodplain eucalypt forests and woodlands	Riverine Chenopod Woodland	91,405	59,545	28,523	27,761	2,607,101,169	1,653,019,034
Wetlands	Sedge Wetland	213,223	206,149	4,352	5,234	927,933,781	1,079,036,307
Cultivated areas	-	-	-	24	29	-	-
Re-sprouter temperate and subtropical eucalypt woodlands	Plains Woodland	50,791	64,160	953	953	48,381,951	61,116,702
Lowland Streams	-	-	-	545	422	-	-

Estimates

The relevant price for $VWAPHH supply by EVC for 2010 and 2015 was converted to an annuity, using the same timeframe and discount rate assumptions as those used to for ecosystem asset valuation (Chapter 7, Ecosystem Supply and Use Accounts). This provided annual exchange values for 2010 and 2015 habitat supply for the 8 focal species. These values are conceptually the same as annual rents for habitat supply for the 8 focal species.

The annuity value relies on a payment formula, where the discount rate is 2.5% the analysis period is 100 years and the present value of the asset is the capital value in the year in question.

Table 45 Annuity Value Estimates

Ecosystem Type	Ecological Vegetation Class	Capital value ($AUD)		Annuity value ($AUD)	
		2010	2015	2010	2015
Gunbower					
Fire-intolerant Callitris woodlands	Creekline Grassy Woodland	5,218,971	5,783,930	142,540	157,970
Inland floodplain eucalypt forests and woodlands	Riverine Chenopod Woodland	1,703,015,582	1,114,609,034	46,512,555	30,442,067
Wetlands	Sedge Wetland	111,595,661	92,664,053	3,047,887	2,530,829
Cultivated areas	-	-	-	-	-

Ecosystem Type	Ecological Vegetation Class	Capital value ($AUD)		Annuity value ($AUD)	
		2010	2015	2010	2015
Re-sprouter temperate and subtropical eucalypt woodlands	Plains Woodland	45,801,115	57,856,556	1,250,914	1,580,171
Lowland Streams	-	-	-	-	-
Koondrook-Perricoota					
Fire-intolerant Callitris woodlands	Creekline Grassy Woodland	60,228,538	66,748,333	1,644,955	1,823,022
Inland floodplain eucalypt forests and woodlands	Riverine Chenopod Woodland	2,607,101,169	1,653,019,034	71,204,831	45,147,055
Wetlands	Sedge Wetland	927,933,781	1,079,036,307	25,343,615	29,470,509
Cultivated areas	-	-	-	-	-
Re-sprouter temperate and subtropical eucalypt woodlands	Plains Woodland	48,381,951	61,116,702	1,321,402	1,669,212
Lowland Streams	-	-	-	-	-

4.7.3 Areas for improvement

This assessment has been based on 8 focal species. These species are a subset of all species present in GKP. The quantification and valuation are only for the 8 species and cannot be scaled to include all species at GKP.

The assessment quantifies suitable habitat for species, but this does not indicate presence of these species. This suitable habitat proxy approach has been used in this example as data on the abundance and distribution of the 8 focal species was not available through CSIRO modelling or other work.

The quantification of species appreciation services relies on a number of strong assumptions including that (1) the species are present in the habitat areas identified as suitable for the species (2) there is an approximate positive relationship between the presence of species and the quality of the hectares used as proxy for species presence, such that increasing the quality of hectares is likely to increase the presence and abundance of the 8 focal species (3) the $VWAPHH can be used as a proxy for species in the absence of more direct monetary valuation measures for the 8 focal species.

Future research should focus on establishing better linkages between land suitability and species presence in the GKP. This could be done by working collaboratively with agencies undertaking on- ground fish and bird monitoring (Webster, 2017). Using an approach based in on-ground monitoring would allow for scaling up of species data using a robust and evidence-based simulation approach.

The use of biodiversity credits for habitat to establish the exchange value of the GKP ecosystem species and appreciation value should only be used as an approximate proxy value if direct species valuation data is not available, either in the form of traded species credits or non-market valuation estimates. For credits to be a perfect proxy, their price would need to be adjusted to offset the difference in ecosystem location between where the credit was originally purchased and the GKP ecosystem that it is being applied to. Additionally, there is potential that additional ecosystem supply from GKP would drive down cost of biodiversity credits in the area. This would mean price adjustments would not be marginal.

Additional research should focus on improving understanding of the welfare values for selected focal species. Recent work has looked to establish the economic value of multiple threatened species and ecological communities in Australia (Gunawardena et al., 2020b). Recent work has looked to establish the economic value of multiple threatened species and ecological communities in Australia (Gunawardena et al., 2020b). If future work is coordinated, there is an opportunity to link this type of species valuation work with species prevalence assessments. This has not been possible in this assessment as:

- (Gunawardena et al., 2020b) establishes welfare estimates for only one of the 8 selected focal species evaluated for these accounts by CSIRO – the Australian Bittern.
- While the species-level assessments in (Mokany et al., 2021) are intended to identify areas of suitable habitat within the potential extent of occurrence of each species, as noted above they do not indicate where each of the 8 species is expected to occur, or the species abundance that is expected to occur. Mokany et al, (Mokany et al., 2021) note that combined with potential errors in the land cover classification, or in translating land cover categories to habitat suitability, areas of suitable habitat with the potential extent of occurrence may be under- or over-estimated, with the result that the "focal species could vary considerably in terms of both their potential extent of occurrence, as well as the estimated areas of suitable habitat" (Mokany et al., 2021). In practical terms these limitations make it difficult to robustly estimate species abundance in 2010 and 2015 from the simulations.

Other work has recently attempted to quantify bequest and existence values for native waterbird and fish species in northern Victoria (Natural Capital Economics, 2019). NCE notes that the estimates are preliminary, based on the analysis approach and assumptions made.

Future work to establish robust and evidence-based welfare values for focal species in GKP and northern Victoria should focus on:

- Establishing better linkages between land suitability and species presence. As discussed above, this could be done by working collaboratively with agencies undertaking on-ground fish and bird monitoring . This would allow for scaling up of species data using a robust and evidence-based simulation approach.
- At time of writing, analysis of willingness to pay surveys for the other GKP focal species, is underway, replicating the approach in Gunawardena (2020b). Estimates using these new figures would likely improve the reliability of the monetary flow estimates for 'species and ecosystems appreciation'.

4.7.4 Accounting outputs

Ecosystem and species appreciation flow tables were compiled in physical terms (Table 46) and exchange value monetary terms (Table 47). Supply and use tables show the relationship between habitat supplied for the 8 focal species, the GKP ecosystem, and households as the user.

Habitat suitability assessment of Gunbower forest identified a total of 17,062 ha in 2010 suitable for the 8 focal species. This varied across habitats with 15,756 ha Inland floodplain eucalypt forest and woodland, 459 ha of wetlands, 765 ha of Re-sprouter temperate and subtropical eucalypt woodlands 70 ha Lowland streams and 7 ha of Fire-intolerant *Callitris* woodland (Table 46). In Koondrook-Perricoota modelling identified a total of 27,750 ha in 2010 suitable for the 8 focal species. This also varied across habitats with 23,116 ha of Inland floodplain eucalypt forest and woodland, 3,681 ha of wetlands, 814 ha of Re-sprouter temperate and subtropical eucalypt woodlands 60 ha of Lowland Streams and 79 ha of Fire-intolerant *Callitris* woodland (Table 46).

Habitat suitability assessment of Gunbower forest identified a total of 13,938 ha in 2015 suitable for the 8 focal species. This varied across habitats with 12,817 ha Inland floodplain eucalypt forest and woodland, 389 ha of wetlands, 636 ha of Re-sprouter temperate and subtropical eucalypt woodlands 72 ha Lowland streams and 7 ha of Fire-intolerant *Callitris* woodland (Table 46). In Koondrook-Perricoota modelling identified a total of 14,659 ha in 2015 suitable for the 8 focal species. This also varied across habitats with 11,207 ha of Inland floodplain eucalypt forest and woodland, 2,829 ha of wetlands, 562 ha of Re-sprouter temperate and subtropical eucalypt woodlands 41 ha of Lowland Streams and 20 ha of Fire-intolerant *Callitris* woodland (Table 46).

Between 2010 and 2015 there was a reduction in area of modelled suitable habitat for the 8 focal species across GKP (Table 46). The greatest reduction in habitat for these focal species was 11,909 ha from 'inland floodplain eucalypt forests and woodlands' ecosystem type in Koondrook-Perricoota. Other significant reductions in Koondrook-Perricoota include 852 Ha wetlands and 252 Ha re-sprouter temperate and subtropical eucalypt woodlands. The largest decrease in habitat for the 8 focal species in Gunbower was 2,929 ha from 'inland floodplain eucalypt forests and woodlands' ecosystem type.

The monetary supply and use table (Table 47) presents the exchange values associated with ecosystem and species appreciation in 2010 and 2015. Ecosystem and species appreciation in 2010 has a total exchange value of around $150 million. The 'Inland floodplain eucalypt forests and woodland' ecosystem type provides the largest proportion of value in both 2010 and 2015. In 2010, this ecosystem type provided around $46.5 million of exchange value from Gunbower ecosystem and around $71 million from the Koondrook Perricoota ecosystem. In 2015, the total ecosystem and species appreciation exchange value fell to around $113 million. In 2015, the 'Inland floodplain eucalypt forests and woodland' ecosystem type provided around $30.4 million of exchange value from the Gunbower ecosystem and around $45.2 million from the Koondrook Perricoota ecosystem.

Table 46 Ecosystem and species appreciation physical supply and use table for 8 focal species, GKP, 2010 and 2015

		Economic units			Ecosystem types											
Supply / Use	Units	House hold	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
2010																
Supply	ha				7	15,756	459	5	765	70	79	23,116	3,681	0	814	60
Use	ha	44,812														
2015																
Supply	ha				5	12,827	389	9	636	72	20	11,207	2,829	-	562	41
Use	ha	28,597														
Change	ha	16,215			-2	-2,929	-70	4	-129	2	-59	-11,909	-852	0	-252	-19

Note: Supply and use of ecosystem and species appreciation is derived from analysis of the GKP ecosystem in 2010 and 2015 yields. Data was measured in ha across the different ecosystem types in Gunbower and Koondrook Perricoota. Confidence in data is moderate. Estimates can be improved with finer scale collection of ecosystem data and the ecological interactions between species in the region. '–' = 0
Source: Data from (Mokany et al. 2021b)

Table 47 Ecosystem and species appreciation monetary supply and use summary table (exchange values) for 8 focal species, GKP, 2010 and 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply/Use	Units	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
2010																
Supply	$ AUD				143,000	46,513,000	3,048,000	-	1,251,000	-	1,645,000	71,205,000	25,344,000	-	1,321,000	-
Use	$ AUD	150,470,000														
2015																
Supply	$ AUD				158,000	30,442,000	2,531,000	-	1,580,000	-	1,823,000	45,147,000	29,471,000	-	1,669,000	-
Use	$ AUD	112,821,000														

Note: The exchange value of ecosystem and species appreciation is derived from estimated habitable hectares of the 8 focal species provided by the GKP ecosystem and are in present value (PV) terms as calculated for 2010 and 2015 respectively. Confidence in estimates is low. Estimates can be improved with finer scale collection of ecosystem data and the ecological interactions between species in the region. '–' = 0

Source: Data from (Mokany et al. 2021b) (Victorian Department of Jobs, Precincts and Regions, 2021 and DPI NSW (2017)

4.8 Water Flow Regulation

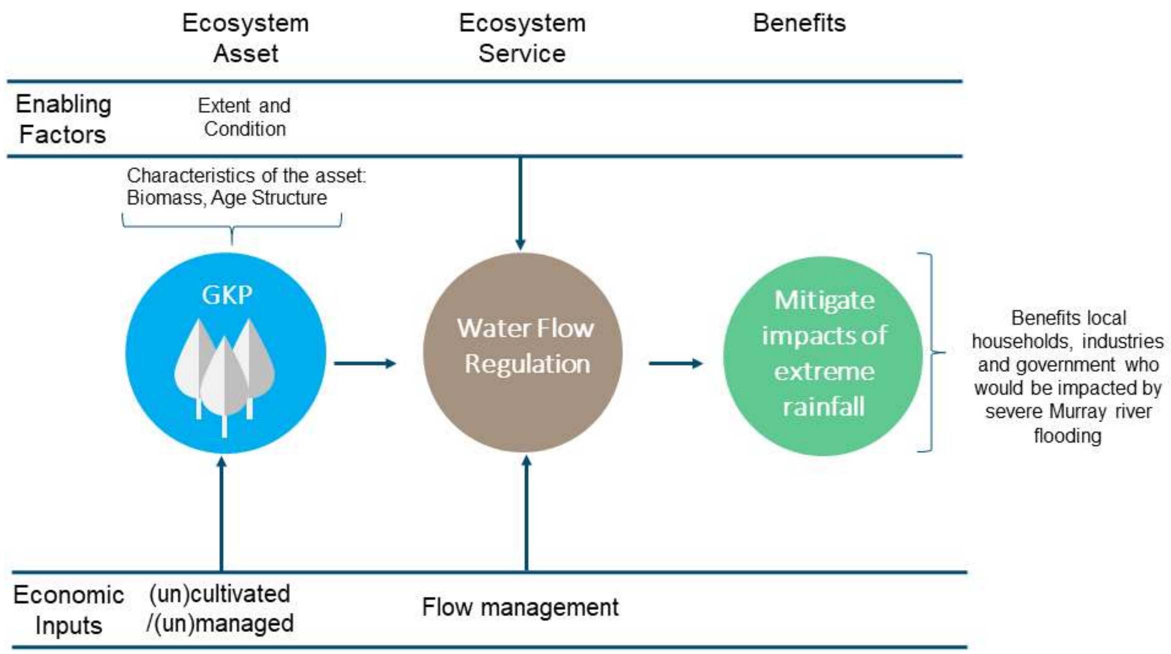
The GKP ecosystem provides water flow regulation as a service to downstream rural and urban communities. This service is quantified as the volume of ecosystem types from the Gunbower, Perricoota and Koondrook forests under differing flood regimes. The direct user of this ecosystem service are the local communities, which benefits from retention of water in the forest that reduces flooding of private land. Figure 25 shows the relationship between the ecosystem service and users.

The main transaction of interest in this context is the relationship between the GKP ecosystem and rural and urban communities. The GKP ecosystem provides variable water regulation under different flow regimes. Management of the capacity to provide water flow regulation is based on management of flood events in the Murray River and irrigation areas.

There are other relationships that are not captured explicitly in Figure 25 but are important to consider in flow regulation. GKP forests naturally require water annually and for extended periods of time to maintain ecosystem assets. Under the current water entitlements there is insufficient water available to meet ecological requirements of the forest system. Extended flooding events provide significant benefit to the ecosystem and have flow on benefits to other ecosystem services.

A complete information set will capture each activity or transaction, estimate the potential value of those transactions, and link them to an ecosystem asset to understand how the attributes and condition of the ecosystem affects the transaction. Government can contribute to the set of information outlined in (Figure 25) to support the ongoing management of the GKP ecosystem.

Figure 25 Water flow regulation



4.8.1 Background

Inflow to Gunbower forest occurs as in-channel flow with inundation via effluent streams, channels and floodplain depressions; and overbank flow where water from the Murray River and channels and moves laterally across the floodplain. Flow thresholds are:

- 13,700 ML/day (at Torrumbarry) via Shillinglaws Regulator on Yarran Creek,
- Between 15,200 ML/d and 27,800 ML/day flow then enters Gunbower Forest from Spur Creek, Barham Cut, Wattles Regulator and Broken Axle Creek. These inflow enter the mid and lower Barham forest. The river reaches bankfull at approximately 27 800 ML/day.

Inflow to Koondrook Forest occurs when River Murray exceeds 16,000 ML/d via two effluents to Swan Lagoon (GHD, 2009). At flows greater than 20,000 Ml/day the forest substantially connects to the Murray River (GHD, 2009).

Bankfull flows in the River Murray occur at about 30,000 ML/d resulting in flooding of Gunbower Forest and Koondrook-Perricoota Forest occurring at flows of 30,000 ML/d and above (GHD, 2009). Modelled flows to 40,000 ML per day are generally evenly split between Gunbower and Koondrook Perricoota forests. A schematic of flow paths in major floods were identified in GHD (2009) (Figure 27).

Urban area impacts

GHD (2014) completed a flood study for Barham township. Levees are overtopped at flow rates greater than 32,000 ML per day (at Barham) which is equivalent to a one in 20 year event. From a flood frequency analysis 2010 floods were a 1 in 5 year event (GHD, 2014). No flooding occurred during 2015.

Koondrook township levees are above the 1 in 100 year event and flood mapping (Floodeye NCCMA, 2021). As a result flooding in Gunbower and Koondrook Perricoota provides limited flood regulation for Koondrook township (NCCMA per comm.)

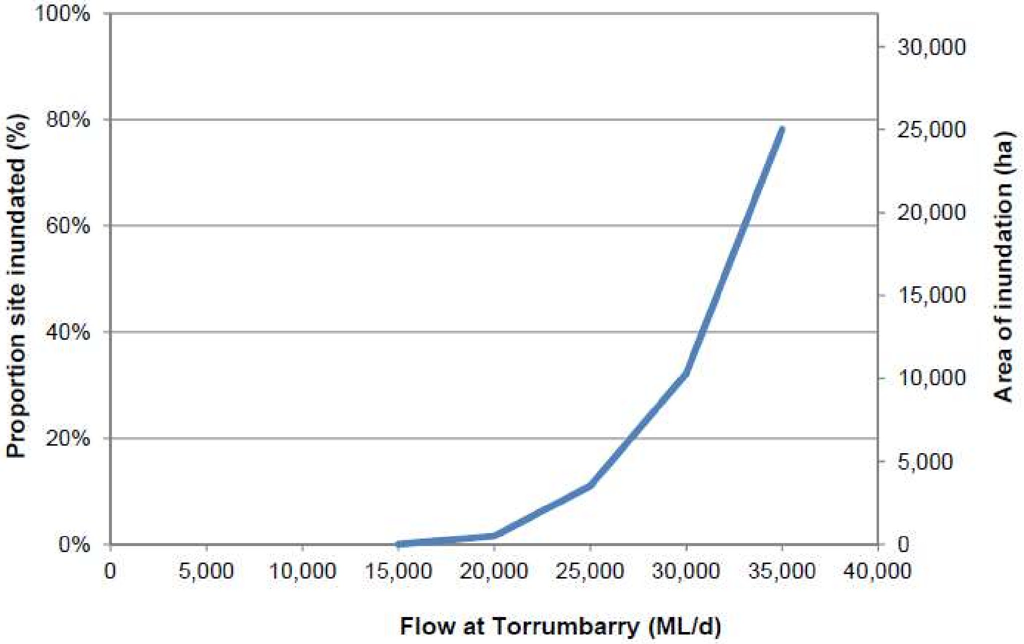


Figure 26 Relationship between inundation and flow for Koondrook–Perricoota Forest (Source: based on analysis of data in NSW Department of Environment and Climate Change 2008) (MDBA 2012)

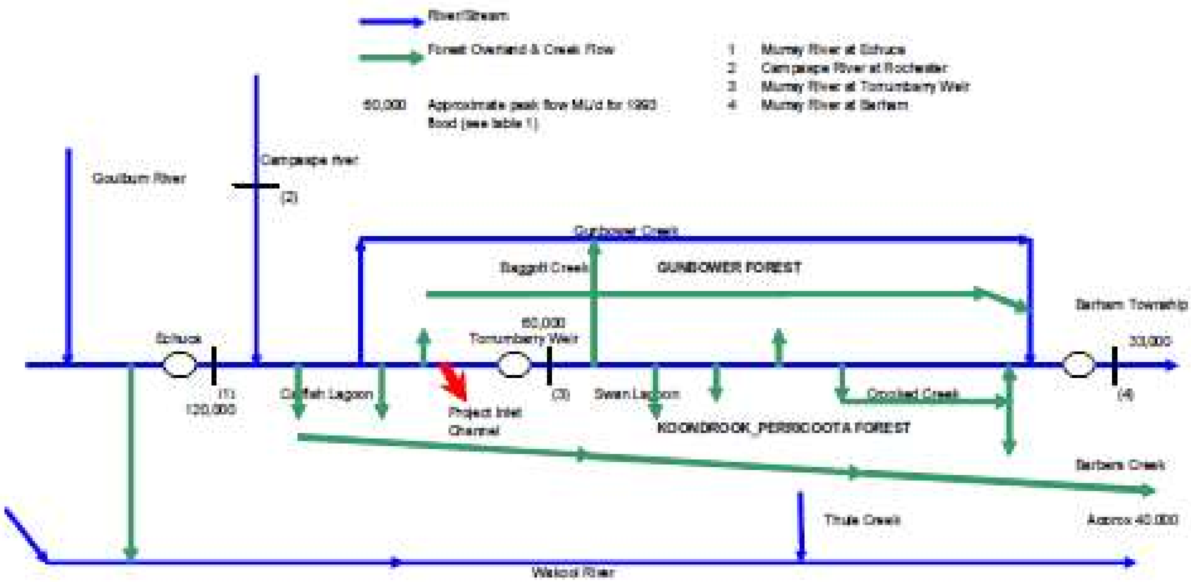


Figure 27 GKP Floodplain flow paths in major floods (GHD 2009)

4.8.2 Method

Options to quantify the physical ecosystem service for water flow regulation were investigated. A summary of the approaches and outcomes are provided below.

Physical ecosystem service accounts – Waterflow regulation

Method

Various options were investigated to develop a method to quantify ecosystem services for water flow regulation. Options to quantify water flow regulation investigated included:

- Review of inundation of GKP using RiMFIM model and daily flows at Torrumbarry and Echuca weir and flood studies for Barham (GHD, 2014).
- Review of MDBA 2016 inundation and depth data
- Comparison of flows between Barham and Torrumbarry gauges

The basis for defining flows was to use a counter factual approach where the quantification would be based on potential downstream flooding of Barham with no attenuation on the floodplain of GKP. The analysis steps included:

- Assess daily flows in 2010/11 at Torrumbarry and Barham gauges, assess likely travel times and calculate differences in flows.
- Review hydrographs to assess correlation with commence to flow thresholds for floodplain effluents and regulators (Shillinglaw and Barham Cut regulators). Review of existing studies (GHD 2009, MDBA 2012) to confirm flow distribution across GKP and reductions in flows between Torrumbarry and Barham gauges
- Assess flow regulation using counter factual analysis assuming the flows above channel capacity of approximately 30,000 ML do not enter GKP floodplain and there is no reduction in flows between Torrumbarry and Barham. These flows would peak around 50,000 ML per day which are significantly greater than 1:100 and 1:200 year events identified in GHD (2014).

The analysis of flow regulation could only identify the total volume and differences in flood peaks from attenuation of flows in Gunbower and Koondrook Perricoota forests. Calculation of the area of inundation downstream that could result as a result of no attenuation on the floodplain was not completed as would require specific hydrological modelling runs and beyond the scope of the investigation.

Estimates

Estimates of the flow peaks attenuated by Gunbower and Koondrook Perricoota wetlands and floodplain are provided in Figure 28. A total flow attenuation estimate over the time period (2010/2011) of 1,325,384 ML.

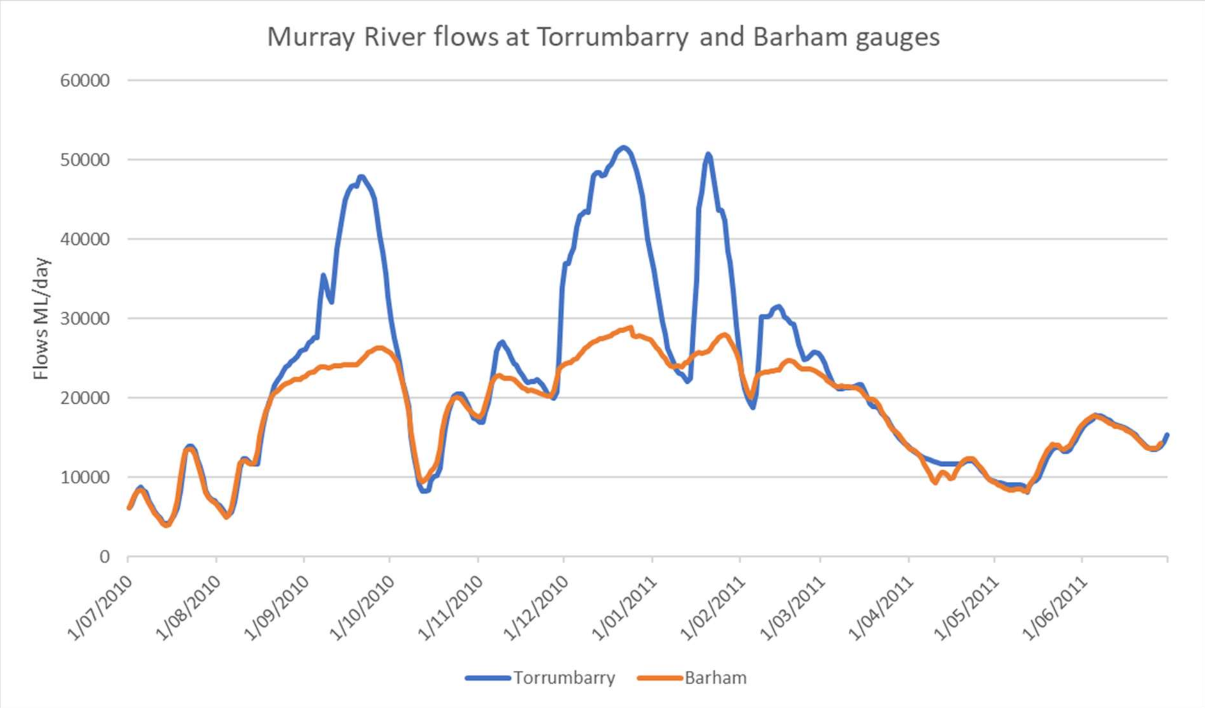


Figure 28 Difference in gauged flows between Torrumbarry and Barham. Flood peaks at Torrumbarry indicate the volume of water stored in GKP forests attenuating flows and reducing flooding in Barham township.

Monetary ecosystem service accounts – Waterflow regulation

The monetary ecosystem accounts water flow regulation can calculate exchange values by applying an avoided damage cost to water flow regulation in 2010 and 2015 respectively.

Given the difficulties in correlating various data sources that provided confidence in the estimates of areas of inundation of GKP forests, flows and downstream impacts we have not estimated the monetary values for water flow regulation. Box 1 provides a summary approach that could be applied in future GKP evaluations, subject to data availability.

Box 1 Approach to producing monetary ecosystem service accounts – Waterflow regulation

The avoided damage cost reflects the value of the water flow (flooding) damage avoided by GKP. Similar to the replacement costs approach, the focus of the damage cost approach is generally on flow regulation provided by GKP ecosystems that are lost if the ecosystem were not present or in a condition such that the flow regulation service could not be provided.

The water flow regulation service in the accounts reflected avoided flood damage costs.

Water flow regulation values are calculated as the difference in monetary flood damage with GKP overbank flows and without GKP overbank flows. End beneficiaries are industry, households and government who would be impacted by flooding. Such that:

$$\$ES_{d,y,i,t,e} = \sum_{y,i,t} \left(V_{y,i,t} * D\right) * 1.2$$

Where:

$\$ES_{d,y,i,t,e}$ is the total value of direct and indirect damage avoided from GKP floodplain water retention (d), in year (y), at geographic location (i), ecosystem type (t), measured as a total direct and indirect damage (e) value.

$V_{y,i,t}$ is the volume of floodwater captured in floodplain in year (y) by location (i), ecosystem type (t)

$D_{s,y,i,t,}$ is the estimated damage to users, calculated using depth-damage functions and spatial inundation modelling for V, if this floodwater had not been captured.

1.2 is the ratio of direct to indirect damage, discussed below

$\sum_{y,i,t}$ shows that the total damage value is the sum of damage value estimates across ecosystem types and locations, for a given year.

Water flow regulation impacts were assessed for the Barham Floodplain Risk Management Area (BFRMA). A general description of how the exchange value of water flow regulation is outlined below:

- The flooding incidence for BFRMA was interrogated for 2010 and 2015. This is summarised in the physical ecosystem accounts described in Various options were investigated to develop a method to quantify ecosystem services for water flow regulation. Options to quantify water flow regulation investigated included: .
- The monetary value of the BFRMA in 2010 and 2015 depends on the likely flooding incidence, extent, duration and impacts. In 2015 there were flooding no events, and hence water flow regulation has a $nil exchange value.
- In 2010 flooding in northern Victoria and in BFRMA would have had different monetary impacts if GKP had not existed and operated to provide water flow regulation services.
- The impact of GKP water flow regulation in BFRMA is calculated using the Rapid Appraisal Methodology (Flood RAM) and revised standard values for RAM (URS, 2009).
- Simulation run outputs from the BFRMA were used to prepare stage-damage curves reflecting the relationships between depth and location of flooding and the assigned monetary value of damages. The assigned value of damages is calculated drawing on information detailing the characteristics of the buildings, agricultural enterprises and infrastructure that will be assessed. The assigned value of damages is calculated using information detailing the characteristics of the buildings, agricultural enterprises and infrastructure in the flood impact areas. This includes data such as floor level, building type, size and condition, agricultural land use type and road type.
- To represent floor level inundation in the absence of floor level survey, residential properties were assumed to incur damages when more than 50% of a property is inundated and the depth of flooding is greater than 150 mm.
- To represent inundation in the absence of survey, commercial and industrial properties were assumed to incur damages when more than 33% of a property is inundated and the depth of flooding is greater than 100 mm.
- To represent inundation in the absence of survey, roads were assumed to incur damagers when inundation depth exceeds 300 mm based on (Olesen et al., 2017).
- Standard Values for agriculture were adopted from (URS, 2009).
- The damages were based on a cadastral layer and planning scheme data. This includes lots that were not developed in 2010 and were yet to be classified as industrial or residential. This approach results in a conservative estimate of damages; this assumption is consistent with the assumptions in the flood mapping.
- The total area of agricultural land and road length were defined by VICMAP dataset.

The methods used to define the biomass for water regulation physical and monetary ecosystem accounts are consistent with or extend methods used or proposed in Australian EEA and natural capital assessments including (UNCEEA, 2021b).

4.8.3 Areas for Improvement

Quantification of water flow regulation of forest areas and wetlands is a complex task and requires access to modelling runs or ability to model scenarios involving floodplain inundation. In urban and highly populated areas where flooding investigations have been conducted, assessment of services is likely to be more straight forward. Quantifying the flow regulation ecosystem service will require flood modelling to provide a counter factual assessment which is not a common approach for flood modelling.

Additional research can also focus on improving the central collection and open access to ecosystem supply data. This analysis collated information on the GKP ecosystem provision services from a number of different sources with varying levels of difficulty. A streamlined approach to data resourcing for use in ecosystem accounting should be organised to assist future calculations. This approach should also incorporate residual rents of ecosystem supply to ensure their accuracy. This would give managers a more complete picture of what their ecosystem is providing to different stakeholders and substantially improve their ability to make management decisions.

4.8.4 Accounting outputs

A waterflow physical supply and use table (Table 48) and monetary supply and use table (Table 49) was developed for the accounting area. Supply and use tables show the relationship between waterflow supplied, the GKP ecosystem, and the government as the user. This approach aligns with the SEEA framework.

The 2015 physical supply and use (Table 48) and monetary supply and use (Table 49) tables are empty to reflect that no flooding events occurred 2015, and GKP did not provide a water regulation service in that year.

Table 48 Waterflow physical supply and use table, GKP, 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply/ Use	Units	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
2010																
Supply	ha				-	-	-	-	-	-	-	-	-	-	-	-
Use	ha			-												
2015																
Supply	ha				-	-	-	-	-	-	-	-	-	-	-	-
Use	ha			-												

Note: Physical supply of use of water flow regulation services has not been analysed due to data availability constraints. '–' = 0

Table 49 Waterflow monetary supply and use summary table, GKP, 2015

		Economic units			Ecosystem type											
					Gunbower						Koondrook - Perricoota					
Supply/ Use	Units	Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams
2010																
Supply	$ AUD				-	-	-	-	-	-	-	-	-	-	-	-
Use	$ AUD			-												
2015																
Supply	$ AUD				-	-	-	-	-	-	-	-	-	-	-	-
Use	$ AUD			-												

Note: Monetary supply of use from water flow regulation services has not been analysed given no physical supply and use could be calculated. '–' = 0

4.9 Ecosystem Services and First Nations Australians

The Gunbower and Koondrook-Perricoota forests and wetlands sustain a wide range of benefits for which members of the Barapa Barapa and Yorta Yorta language groups have acknowledged cultural obligations and access.

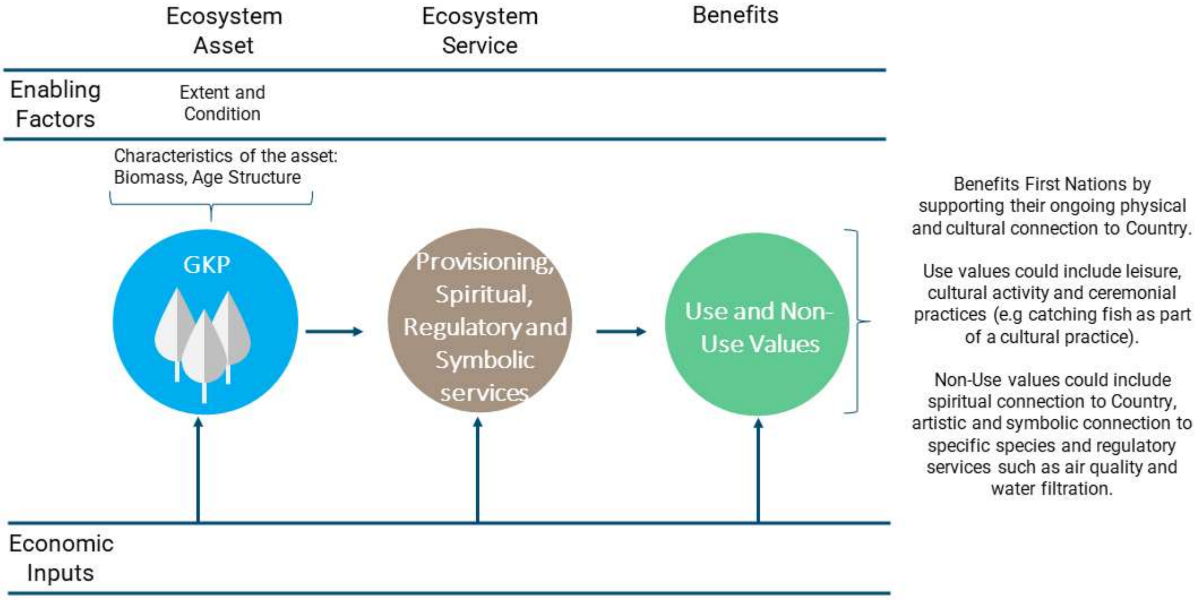
First Nations cultural values, obligations and access are recognised in Commonwealth legislation (*Native Title Act 1993*; *Environment Protection and Biodiversity Conservation Act 1999*; National *Water Initiative 2004*; *Aboriginal Heritage Act 2006*; *Water Act 2007*), the Murray-Darling Basin Plan (2012), and early scholarly works commissioned by the MDB Commission such as Jackson et al. (2010). Cultural obligations to Country take place in everyday life, as Nation business under First Nations governance systems, and within joint management partnerships with philanthropic and government agency programs (ARTD, 2017). The study site is no exception to such arrangements supported by the North Central CMA and the MDBA's The Living Murray Aboriginal Partnerships program. There is also the opportunity for First Nations to be engaged in water management through the Murray Lower Darling River Indigenous Nations (MLDRIN) and Northern Basin Aboriginal Nation (NBAN) governance groups funded by the MDBA to advise on water policy.

Native title claims to the lands that contain the Gunbower Koondrook and Perricoota forests and their waterways have been unsuccessful. The extent to which Nation business is addressing these issues is not discussed here. While maps with boundaries may not be constructive under these circumstances, such complexities should not exclude First Nations from ongoing research into environmental accounting methods where the benefits have direct value to those language groups. First Nations' claims, interests and perspectives are integral to methodological developments with potential for national application and interest, such as LEAP.

The extent to which the SEEA EA (UN CEEA, 2021) treatment of cultural services meets Australian First Nations beneficiaries' expectations is a topic of ongoing investigation. Currently the ecosystem account standard includes 'Spiritual, artistic and symbolic services' as a subset of 'cultural services'. This standard reflects both use and non-use values but does not adequately reflect the use of other services such as regulatory and provisioning services.

In the SEEA EA framework, ecosystem services that can be linked to First Nations will vary depending on the context but may include provisioning services (e.g., fishing) and spiritual, artistic and symbolic services obtained through inherited cultural connection. The cultural connection between First Nations and their land (known as "Country") is part of a living culture; the cultural services derived are diverse and extend beyond spiritual, artistic and symbolic services. They may overlap with provisioning services and have economic and commercial value. First Nations also benefit from the various regulatory services provided by the ecosystem. The Echuca Declaration (MLDRN, 2008, NBAN, 2010) is a covenant operating in this category, defining "cultural flows" as a right to Indigenous Nations water entitlements to support social, economic, cultural spiritual and environmental conditions. A subset of ecosystem services provided to First Nations by GKP ecosystem is proposed in Figure 29.

Figure 29 Suggested supply of ecosystem services to First Nations groups in the study site



While being a global organising framework, the UN SEEA is a stranger to most First Nations peoples, and yet its business is fundamentally their own – valuing the services that ecosystems generate to sustain life and culture. Within the Murray-Darling Basin several ecosystem assessment studies set baselines that included "cultural" services, but only two such studies included First Nations in the work (Ngarrindjeri Nation and Birckhead et al, 2011; Ngemba Nation and Maclean et al, 2012). Other studies relevant to the case study sites and involving First Nations include the Aboriginal Waterways Assessment work carried out by MLDRIN with Barapa Barapa (Mooney & Cullen, 2019), DELWP's compilation of First Nations' contributions to Victoria's water resource plans involving all three Nations relating to the study site (2019), the McConachie et al (2020) participatory cultural mapping study of the Gunbower Forest with Barapa Barapa Nation representatives, the Pardoe and Hutton study also working with Barapa Barapa into the archaeology of a wetland village at Pollack Swamp in Koondrook-Perricoota Forest (2020). These studies do not relate to UN-SEEA but they provide information that makes First Nations' preferred approaches to knowledge about ecosystems and their benefits visible.

Translating these preferences to the UN SEEA requires cross-cultural engagement to consider the consequences of use and cultural implications of the UN SEEA framework to Basin First Nations. Work may follow on ecosystem benefits and their valuation, monetary and otherwise, as articulated by the Nations. This work has been discussed with Basin Nations and is in view for the Murray-Darling Water and Environmental Research Program (2021-25) with implications for the LEAP Commonwealth Partners and the CSIRO.

4.9.1 Cross cultural protocols

Barapa Barapa have stressed that any engagement regarding Country needs to have Barapa Barapa people involved from the outset; Yorta Yorta exert the right to Free Prior Informed Consent when engaging within their Traditional lands (DELWP, 2019). In some texts Wemba Wemba Nation is included as a Nation with cultural connection to the Gunbower study site, and multiple Nations are identified with interests in the Koondrook-Perricoota Forest in consideration of habitation prior to European arrivals (Harrington et al, 2011).

Australian governments and research organisations are aware of standards of cross-cultural engagement to ensure First Nations' self-determination. Such standards are:

- The United Nations Declaration of the Rights of Indigenous Peoples (2007) which refers to the principles of Free, Prior and Informed Consent endorsed by the United Nations Permanent Forum on Indigenous Issues (UNPFII) at its Fourth Session in 2005 to which Australia became a signatory in 2009
- The Australian Institute for Aboriginal and Torres Strait Studies Code of Ethics (2020) which built on earlier work (1999) and which guides the formation of partnerships, design and planning of research projects in reference to Aboriginal knowledge systems
- The Nagoya Protocol on Access and Benefit Sharing under the Convention on Biological Diversity includes recognition of the need to recognise traditional knowledge of genetic resources and make provisions of access and benefit sharing an element of Free, Prior ad Informed Consent
- The CARE principles for Indigenous Data Governance which is an international standard complying with the United Nations Declaration of the Rights of Indigenous Peoples, relating to self-governance and authority to control inheritances and cultural assets as captured in data, data ownership, management and use. These principles are reflected in Productivity Commission's Australian Government's Indigenous Program Evaluation Strategy (2020).

Over and above the local and conceptual complexities discussed above, the limitations of project resourcing, competing demands on participant time, and the impacts of the global pandemic meant the above standards could not be followed for this current work. To ensure that First Nations' voices are included in the LEAP case study reporting, a synthesis of published works that have complied with these standards is presented here.

4.9.2 Understandings

One Christmas we went out to the Gunbower Forest near Koondrook with five families… You could see shrimps and yabbies swimming in the shallow water. When you did go out you were sure to catch cod, silver bream or perch and red fin… Plant life that was used for medicinal purposes were plentiful too – like Old Man Weed. Also your reeds and Nadu plants… there were the river mussels and the tree grubs too. Tree grubs are a food source too. (Elder, Aboriginal Submissions Database, 2013, MDBA)

Barapa Barapa has developed an assets framework for their Country with substantial detail about the extent and condition of those assets (DELWP, 2019). It is made up of the following distinctions:

- Plants
- Animals
- Water
- People

- Cultural heritage: tangible
- Cultural heritage: intangible
- Kulayatang (wet)
- Cultural plants
- Yumurrki (Dreaming)
- Yawir (fish)
- Tya (soil/land)
- Kunawar (Black Swan)

Taking this work and other studies into account, the concept as developed by Barapa Barapa is important for the LEAP to consider. It should also include Barapa Barapa Nation's cultural knowledge of and obligations for the regulatory, provisioning and cultural services of:

- Surface and ground water supply and quality
- Land and water food webs for provisioning
- People and all living things as part of ecosystems as cultural connection
- The importance and meanings of heritage, culturally significant places and species as cultural identity
- Spiritual appreciation within Country as a connected living system for culturally specific health and wellbeing.

Benefit sharing related to Barapa Barapa Country as stated in the framework and other works includes:

- Employment and economic participation in water- based businesses, trading and networks
- Cultural and social wellbeing, including physical health, artistic expression, habitation, freedom of movement, storytelling, and cultural education on Country
- Participation in cultural practices such as women's and men's business, protecting Country and knowledge, traditional harvesting and related ceremony, consumption and production, hunting, fishing and burning, and centrality to management decisions about Country (McConachie et al 2020, Mendham & Curtis, 2015, Pardoe & Huttom, 2021)

Barapa Barapa Nation will not benefit from the ecosystem services that underpin their cultural knowledge systems, and fund their cultural economies, their social and individual wellbeing if water management does not include culturally distinguished environmental functions. Particular to First Nations is legislative and regulatory reform which repositions their preferences in natural resource management and addresses the legacies of historic and forced removal from lands. Such work is ongoing but how it is to be accounted for is not resolved.

Yorta Yorta Nation have been included in published consultations and research about Country both with Barapa Barapa and other Nations, and with independent scholars including Yorta Yorta scholars. The latter have been focussed on conceptual work related to ecosystem services and natural resource management, but not publicly applied to the specific characteristics of

Yorta Yorta Country at the LEAP study site. The only observations that can be made from available material related to the study sites and to which Yorta Yorta Nation contributed, are:

- The Barapa Barapa assets framework cannot be assumed to apply to Yorta Yorta or any other Nation
- Adaptation to climate change is likely to have some synergies with Yorta Yorta customary law and practices as it will require longer time frames (Griggs et al 2013 cited in Strong, Allen & Finlayson, 2017; Lynch et al, 2012)

The North Central CMA's work on sustainable land management which included both Barapa Barapa and Yorta Yorta Nations amongst others, makes a comprehensive summarising statement:

> *There are many important places for Aboriginal people across north central Victoria. These areas are important for various reasons including obtaining sustenance, expressing themselves artistically, passing on creation stories and cultural values, engaging in conflict, establishing alliances and social networks, trading goods, celebrating rites of passage and committing the departed to their final resting places. Underpinning these material aspects of Aboriginal cultural heritage are intangible places where there may be no physical evidence of past cultural activities. These include places of spiritual or ceremonial significance, places where traditional plant or mineral resources occur, or trade and travel routes. Information about such places may be passed down from one generation to the next or may survive in nineteenth century documents and records. (NCCMA, 2013, p.144)*

4.9.3 Knowledge gaps

There are several knowledge gaps that need to be resolved for future work with First Nations in the LEAP, including:

- How to engage with Nations on agreeing an approach that links the UN SEEA with national accounts and local First Nations approaches to identifying, managing and sharing benefits from ecosystem services
- How to ensure First Nations' rights to benefits are not overtaken by non-indigenous specific developments
- Other matters related to codifying, measuring and valuing benefits, including the use of such information for decision support will be addressed on the first two being resolved.

4.9.4 Areas for improvement

- Progress this work through the MD-WERP in partnership with MLDRIN and NBAN
- Simultaneously plan for and fund dialogue with Nations relating to future ecosystem assessments within the LEAP from the earliest stages of such work
- Link such developments to national scale First Nations groups such as the National Association of Community Controlled Health Organisations, and impacted

Commonwealth agencies such as the National Indigenous Australians Agency and jurisdictional bodies who have already made significant strides in this work

4.10 Recreation-related services

Recreational activities include people's experiences in the GKP environment. Recreation-related services are used by households and the characteristics and condition of the GKP ecosystem may impact the quantity of services that households demand.

Households can engage the tourism industry to participate in recreation activities in the GKP, or they can consume them directly (household consumption), for example in the case of recreation-based fishing. There is thus an important link between the ecosystem, its condition, the species that inhabit it, and recreation services.

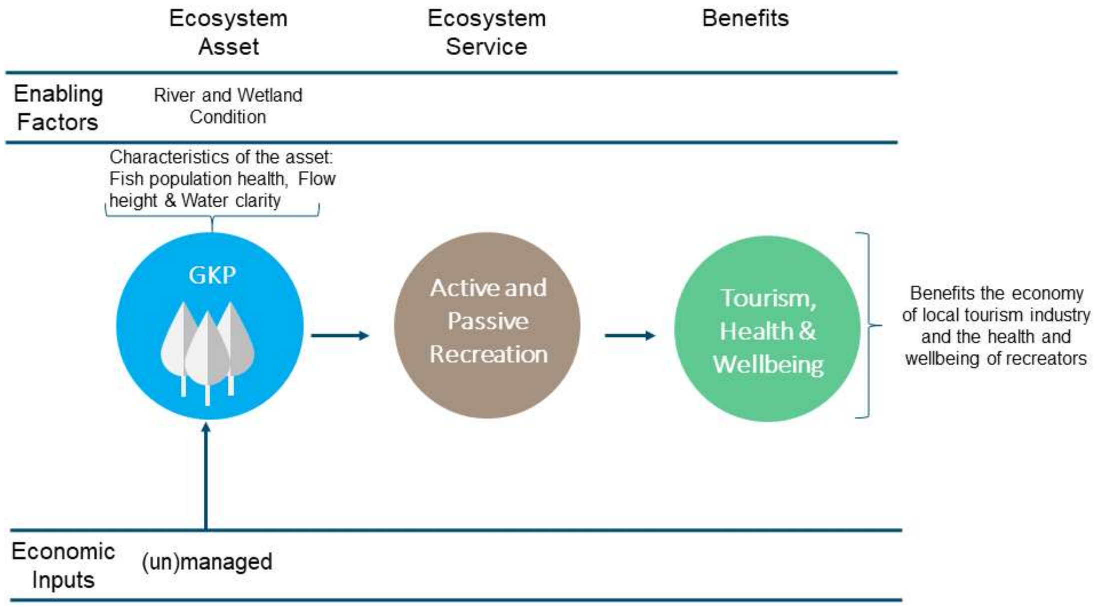
The main transaction of interest in this context is the relationship between the GKP ecosystem and recreation-related services. Figure 30 shows the relationship between the ecosystem service and people.

There are other relationships that are not captured explicitly in Figure 30 but are important to consider in recreation demand. For example – recreation demand will also be determined by factors such as the type and quality or accommodation, and services provided in towns surrounding GKP. For people undertaking multi-destination and multi-purpose trips, the location and proximity of these other destinations and purposes will also play a part in determining how often and how long people visit GKP.

The link between the ecosystem (quantity and quality) and the recreation activity (visitors and visit days) are key components of the narrative. The quantity and quality of GKP assets can affect the quantity of all recreation transactions now and into the future.

A complete information set will capture each recreational activity or transaction, estimate the potential value of the recreation transactions, and link them to one or more ecosystem assets to understand how the attributes and condition of the ecosystem affects the transaction. Government can contribute to the set of information outlined in Figure 30 to support the ongoing management of the GKP ecosystem.

Figure 30 Recreation-related services



4.10.1 Literature review

Current SEEA guidance recommends the ecosystem services supply and use physical account records a supply and corresponding use for each recreational visitor interaction. The supply should be shown from the relevant ecosystem type and households as users of the service. Flow should be recorded irrespective of the degree to which there is involvement of businesses in facilitating or supporting the activity (United Nations Department of Economic and Social Affairs Statistics Division, 2021).

In addition, a supplementary row to the use of ecosystem services should be recorded showing the connection between the ecosystem and relevant businesses. SEEA guidance notes this entry does not imply the need to record additional supply, but provides complementary data on the use of ecosystem services (United Nations Department of Economic and Social Affairs Statistics Division, 2021).

Ecosystem supply and use accounts for interactions are often limited to measuring visits, based on available data in satellite accounts (Keith et al., 2016). Other accounts have recorded actual visit counts using survey or ticket sale data (Stewart et al., 2020).

Current SEEA guidance (United Nations Department of Economic and Social Affairs Statistics Division, 2021) identifies one way to obtain an equivalent to the exchange value of trips to recreation sites involves adding up all consumption expenditures enabled or enhanced by nature. This is sometimes referred to as the consumption expenditure approach. Examples where the consumption expenditure approach has been used include in the Green Triangle accounts (Stewart et al., 2020) and the UK 2021 tourism and outdoor leisure natural capital accounts (Davies & Dutton, 2021).

The simulated exchange value method (SEVM) (Badura et al., 2018) has also been used to value recreation in the context of EEA. SEVM uses revealed (actual recreation travel) or stated (stated, or so call contingent behaviour data) preference data, to simulate the price and the quantity that would prevail at a static equilibrium an ecosystem service was traded in a market. The approach can provide an estimate of the direct exchange value required for entry into the accounts based on the exchange value concept. Some authors have noted the application of this approach is currently limited by restrictive assumptions relating to demand specification, and data requirements (Caparrós et al., 2017).

There are different views about expenditure items to include in recreation accounts and whether the inclusion of the value of time is compliant with accounting principles. Guidance therefore recommends providing consumption expenditure estimates separately, and the value of time separately (United Nations Department of Economic and Social Affairs Statistics Division, 2021). For example, the UK 2021 tourism and outdoor leisure natural capital accounts (Davies & Dutton, 2021) separates expenditure by Transport and travel; Food and drink; Entrance tickets; Accommodation; Shopping; and Other.

4.10.2 Method

Physical and monetary ecosystem service accounts were produced in this analysis. A particular focus of the ecosystem service accounts was to integrate the account ready extent and condition data outlined in the previous chapters.

Detailed methods for both ecosystem service accounts are outlined in below. All datasets relied on for the analysis of ecosystem services are referenced at the bottom of the account tables.

Physical ecosystem service accounts – Recreation-related services

Method

The number of visitor days to GKP can be used as a measure of recreation-related ecosystem service supply. The number of visitor days to Gunbower, KP and GKP in 2010 and 2015 have been estimated directly for the populations of Victoria, New South Wales and ACT, and South Australia. Using visitor days as the basis for supply and use provides a more accurate linkage between ecosystem supply and recreational use than visitor numbers.

Domestic day visitor days[2] and domestic overnight visitor days[3] are estimated using results from a dedicated online survey conducted in March 2021. Respondents were drawn from a professional survey provider database, Pureprofile. The online survey included approximately 1,300 respondents from ACT and NSW, 1,100 from Victoria and 560 from SA.

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[2] Defined as visitors from ACT, NSW, Victoria and South Australia of any age who travel for a round trip distance of at least 40 kilometres, and are away from home for at least one hour, and do not spend a night away from home as part of their travel. Same day travel as part of overnight travel is excluded https://www.tra.gov.au/tra/2016/Tourism_Region_Profiles/Region_profiles/index.html

[3] Defined as visitors from ACT, NSW, Victoria and South Australia of any age who undertake trips that involve a stay away from home of at least one night, but less than one year, at a place at least 40 kilometres from home.

The survey instrument is available on request from the authors. The survey (1) asked respondents about household details, including residential postcode (2) showed respondents a map and provided background details about the GKP (3) asked respondents if they had ever visited GKP between 2010 and 2021.

If respondents said they had visited GKP between 2010 and 2021, respondents were asked whether they visited (i) Gunbower National Park (NP) only; (ii) Koondrook-Perricoota State Forest (SF) only; or (iii) both Koondrook-Perricoota and Gunbower.

Respondents then completed separate visitor surveys for the Gunbower NP and Koondrook-Perricoota SF depending on which sites they had visited. Respondents who had visited Gunbower and Koondrook-Perricoota completed both surveys.

The visitation surveys asked respondents standard visitation questions needed to generate zonal travel models, consistent with earlier evaluations (Stoeckl & Mules, 2006) (Gillespie et al., 2017) (Dyack et al., 2007). These questions included obtaining information on group size, visit duration, activities during the visit, and accommodation type (if overnight).

Respondents were also asked whether their visit was part of a multiple destination visit. Where the visit was part of a multi-destination visit, respondents were asked about the relative importance of the GKP visit based on (i) the number of days they visited GKP out of the total days visiting and (ii) using an importance weight (scored as 0% for no importance to 100% as the primary reason).

Finally, respondents who had visited GKP were also asked about their future visit intentions in the next two years. Respondents were then asked, based on their answers, whether **a noticeable change** in any of the following would change the number of times they would expect to visit in the next 2 years: (i) increase or decrease in native fish abundance, such as Murray Cod and Golden Perch (ii) increase or decrease in migratory bird abundance, such as Eastern Bittern and (iii) increase or decrease in health and / or abundance of native vegetation. This contingent behaviour questioning approach provides some evidence base for understanding how future recreation demand could be linked to ecosystem services provided at the GKP, and how changes in ecosystem condition at GKP could alter recreation uses. The contingent behaviour approach is consistent with earlier contingent behaviour approaches for natural assets such as National parks (Dyack et al., 2007; Gillespie et al., 2017).

Survey results were used to estimate population weighted domestic day and overnight visitor numbers, and domestic day and overnight visitor numbers by reported recreation activities. Survey responses were reweighted using iterative proportional fitting, so they were representative of the NSW and ACT, Victorian and South Australian populations by location (metro versus regional for NSW, Victoria, and SA), age, gender, and income.

Recreational activities supply and use estimates are developed using visitor to population ratios for NSW and ACT, Victoria and SA. Estimates are based on the observed visitation rate from the weighted survey results, and the population of that zone, such that:

$$V_{y,i,z} = \frac{v_{y,i,z,d} + v_{y,i,z,o}}{n_z} * Pop_{y,z}$$

Where:

$V_{y,i,z,o,a}$ is the estimated number of visitor days in year (y), at geographic location (i) from travel zone (z)

$v_{y,i,z,d}$ is the survey weighted number of recreational visits reported by survey respondents in year (y), at geographic location (i) from travel zone (z), that are day trips (d).

$v_{y,i,z,o}$ is the survey weighted number of recreational visits reported by survey respondents in year (y), at geographic location (i) from travel zone (z), that are overnight (o)

n_z is the survey weighted number of total survey respondents for travel zone (z). This includes all respondents, those who said they had travelled to Gunbower and / or Koondrook-Perricoota during 2010-21 and those who said they had not.

$Pop_{y,z}$ is the resident population of travel zone (z) in year (y).

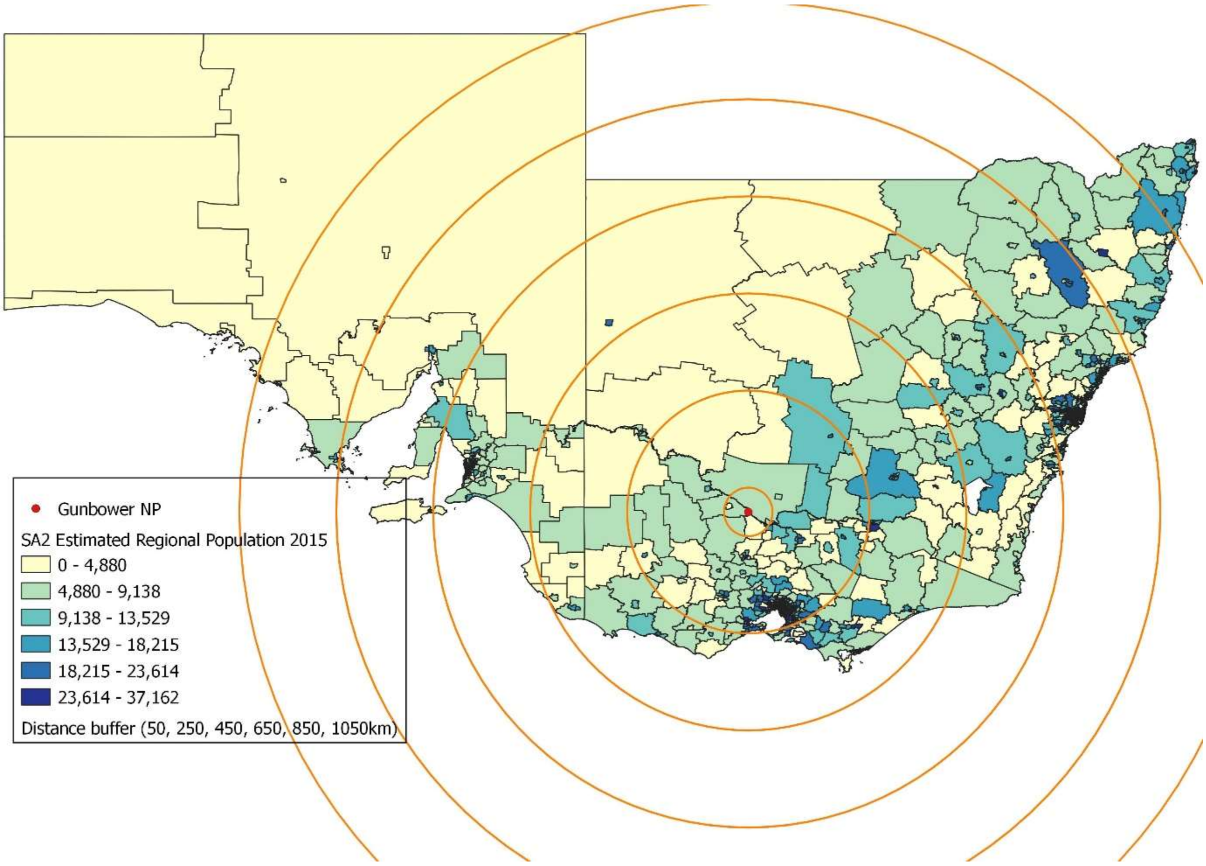
Travel zone (z) was separated by State (NSW and ACT, VIC, SA) and zonal distance measured as a most direct route from the respondent's postcode to Gunbower NP or KP using Google Maps application programming interface (<50kms, 51-250kms, 251-450kms, 451-650kms, 651-850kms, 851-1,050kms and 1,051kms+). Resident population in 2010 and 2015 by zone were extracted from ABS geopackages[4].

People under the age of 17 did not complete the survey. To include under 17 in the visit estimates we estimated visit days within the population by zone by adjusted for the number of people 17 and under living in the zone, and the incidence of under 17-year-olds visiting GKP as part of a group, based on the reported survey results.

Visitation estimates were compared with other recreation surveys of the Gunbower NP and NSW protected areas (E & Curtis, 2018; Heagney et al., 2019; Natural Capital Economics, 2019), and local tour and park operators, to test what the survey results are suggesting in terms of visitation counts.

[4] https://www.abs.gov.au/statistics/people/population/regional-population/2018-19#data-downloads-geopackages

Table 50 ERP by zone, 2015



Estimates

Estimates used to generate the accounting outputs in Table 66 are summarised below by zone.

Table 53 shows total survey respondents by zone and the reported visit incidence (visits per adult) for 2015 and 2010 from these respondents. Sample sizes for <50 kilometres and 850 kilometres plus are small and may have small sample issues as a result.

There is a noticeable increase in self-reported visitation for zone 650-850 kilometres, which includes most of the Greater Sydney population. Self-reported visitation rates for the Greater Sydney population zone are higher than for the Greater Melbourne population (50-250 kilometre) zone. This is inconsistent with expectations – ground-truthing with local caravan park operators and Gannawarra Shire Council both suggest more visitors come from Greater Melbourne than Greater Sydney.

One possible explanation for this result is that Greater Sydney respondents over-reported visitation in 2010 and 2015. This may have occurred if (1) they could not recall visits to the region in 2010 or 2015 (2) respondents exhibit a response bias, such as a social desirability bias in their responses (3) there was confusion about the location of GKP.

Because there is no way to retrospectively assess the size of any potential reporting bias in the Greater Sydney respondents, we include results based on Greater Sydney respondents self-reported visitation incidence. For comparison, we also include visitation rates assuming the Greater Sydney population has the same levels of visitation as the Greater Melbourne population in 2010 and 2015. These results are shown as Greater Sydney=Greater Melbourne* (GS=GM*) in the Tables and Figures in this section.

Table 56 and Table 57 highlight that respondents who said they had visited GKP previously indicated they would potentially increase visits to G and KP in the next two years if there was a noticeable improvement in migratory bird abundance, native fish abundance and / or condition and abundance of native vegetation. The average increase in the number of trips ranges between 0.4 to 0.9 additional trips over the two years for G and KP. Noticeable decreases in the condition of these things may also result in small decreases in future visits. These results suggest that recreators with experience of GKP are more responsive to improvements in condition in GKP than decreases in condition, measured in terms of future recreation visits.

Table 51 Estimated residential population by zone, 2015

Distance	New South Wales	Victoria	South Australia	Total
Total	7,616,168	6,022,322	1,700,668	15,339,158
0-50km	5,849	7,737	-	13,586
50-250km	88,839	5,331,136	-	5,419,975
250-450km	237,733	676,921	97,372	1,012,026
450-650km	708,002	6,528	1,463,221	2,177,751
650-850km	5,912,364	-	96,874	6,009,238
850-1,050km	402,492	-	36,034	438,526
>1,050km	260,889	-	7,167	268,056

Table 52 Estimated residential population by zone, 2010

Distance	New South Wales	Victoria	South Australia	Total
Total	7,144,292	5,461,101	1,627,322	14,232,715
0-50km	5,263	7,941	-	13,204
50-250km	88,066	4,813,289	-	4,901,355
250-450km	232,751	633,058	95,207	961,016
450-650km	681,765	6,813	1,393,576	2,082,154
650-850km	5,494,242	-	95,121	5,589,363
850-1,050km	390,238	-	36,229	426,467
>1,050km	251,967	-	7,189	259,156

Table 53 Respondents by zone and reported visit incidence (visits per adult) 2015, 2010

	Unweighted	Weighted	Gunbower		KP	
Distance			2015	2010	2015	2010
Total	2,968	2,966				
0-50km	9	10	1.919	0.993	0.163	0.264
50-250km	922	976	0.027	0.018	0.014	0.010
250-450km	244	262	0.013	0.011	0.007	0.001
450-650km	943	788	0.023	0.019	0.019	0.022

650-850km	723	770	0.047	0.042	0.060	0.030
GS=GM*			0.027	0.018	0.014	0.010
850-1,050km	75	102	0.033	0.018	0.044	0.018
>1,050km	52	58	0.018	0.043	0.024	.001

Table 54 Estimated visits by zone, 2015, 2010

distance	**Gunbower**		**KP**	
	2015	2010	2015	2010
Total	346,000	252,000	139,000	84,000
Total (GS=GM*)	252,000	156,000	88,000	55,000
0-50km	16,000	8,000	1,000	2,000
50-250km	92,000	57,000	32,000	16,000
250-450km	8,000	1,000	1,000	1,000
450-650km	32,000	25,000	15,000	17,000
650-850km	182,000	149,000	80,000	42,000
850-1,050km	9,000	4,000	6,000	2,000
>1,050km	3,000	4,000	1,000	1,000

Table 55 Average visitor days by zone, 2015, 2010

distance	**Gunbower**		**KP**	
	2015	**2010**	**2015**	**2010**
Total	453,000	290,000	158,000	91,000
Total (GS=GM*)	379,000	208,000	110,000	66,000
0-50km	24,000	11,000	1,000	1,000
50-250km	140,000	76,000	42,000	21,000
250-450km	8,000	1,000	1,000	1,000
450-650km	53,000	37,000	17,000	19,000
650-850km	205,000	149,000	87,000	46,000
850-1,050km	14,000	7,000	7,000	3,000
>1,050km	5,000	6,000	2,000	1,000

Table 56 Based on your answer to the last question, would a noticeable change in any of the following at Gunbower change the number of times you would expect to visit in the next 2 years? Noticeable change future intentions, visits Gunbower

	Mean	**Std Error**	**Lower 95% CI**	**Upper 95% CI**
Decrease in migratory bird abundance, such as Eastern Bittern	-0.03	0.17	-0.39	0.30
Decrease in native fish abundance, such as Murray Cod and Golden Perch	-0.04	0.17	0.38	0.33
Decrease in health and / or abundance of native vegetation	-0.10	0.17	-0.43	0.23
Increase in migratory bird abundance	0.78	0.15	0.49	1.07

Increase in native fish abundance	0.86	0.14	0.58	1.15
Increase in health and / or abundance of native vegetation	0.78	0.14	0.52	1.05

Table 57 Based on your answer to the last question, would a noticeable change in any of the following at KP change the number of times you would expect to visit in the next 2 years? Noticeable change future intentions, visits KP

	Mean	Std Error	Lower 95% CI	Upper 95% CI
Decrease in migratory bird abundance, such as Eastern Bittern	-0.19	0.18	-0.55	0.16
Decrease in native fish abundance, such as Murray Cod and Golden Perch	-0.16	0.17	-0.50	0.17
Decrease in health and / or abundance of native vegetation	-0.12	0.17	-0.47	0.23
Increase in migratory bird abundance	0.90	0.15	0.61	1.19
Increase in native fish abundance	0.41	0.17	0.07	0.76
Increase in health and / or abundance of native vegetation	0.81	0.15	0.51	1.11

Monetary ecosystem service accounts – Recreation-related services

Method

In this GKP application we have used the consumption expenditure approach. This approach broadly aligns with and improves earlier work estimating recreation visitation at Gunbower (NCEconomics, 2020) and other recreation demand studies evaluating demand for on- and near-water activities in Australia (Gillespie et al., 2017). A travel cost model was not estimated in this evaluation, given the limitations of the Greater Sydney survey results, and the risk that a travel demand model using Greater Sydney recreation counts would produce biased estimates.

In the GKP application, consumption expenditure is interpreted as a proxy for the exchange value reflecting the amount people would be willing to pay additional to the actual consumer expenditure incurred. Under this interpretation we would assume that if the ecosystem did not exist, these expenses would not be made. Hence, the additional consumption expenditure is interpreted as the exchange value of the ecosystem contributions. Note here that using this approach the exchange value might be overstated given price elasticities of demand are ignored (UNCEEA, 2021).

Consumption expenditure on recreation at GKP is defined as:

$$\$\mathrm{RCE}_{y,i,z} = \left(2 * D_{y,i,z} * TC_y\right) + \left(v_{y,i,z,d+o} * SC_y\right)$$

Where:

$\$\mathbf{RCE}_{y,i,z}$ is the consumption expenditure cost for recreation in year (y), at geographic location (i) from travel zone (z).

2 accounts for the return trip.

$D_{y,i,z}$ is the distance in year (y) from geographic location (i) and the originating travel zone (z)

TC_y is the cost per kilometre to travel to the site. This cost includes vehicle cost and the opportunity cost of travel time.

$v_{y,i,z,d+\boldsymbol{o}}$ is the estimated number of visitor days (d) and overnight visitor days (o) in year (y), at geographic location (i) from travel zone (z).

$\boldsymbol{SC_y}$is the cost incurred while at the recreation site, including accommodation costs and the opportunity cost of visit time (excluding travel time).

Recreators may visit GKP as part of a multi-destination and / or multi-purpose trip. In this case, trip costs need to be apportioned across destinations, otherwise consumption expenditure will be overstated for the GKP trip. Our approach to attributing values for multi-destination and multi-purpose trips follows (Driml et al., 2020; Dyack et al., 2007; Martinez-Espineira & Amoako-Tuffour, 2009) by using an importance scale. This approach is subjective, but it considers that the importance of visits is unlikely to be simply a function of the time spent by the multi-destination visitor on each destination. For respondents who reported visiting Gunbower and Koondrook-Perricoota in the same trip, costs are apportioned based on time reported spent in each location.

The opportunity cost of time is calculated assuming direct travel time (i.e. the lowest opportunity cost of time). For adults, the opportunity cost of travel time was assumed to be 35% of the median for Statistical Subdivision the population comes from. For persons under 18 and over 65 years, the opportunity cost of travel time was taken at a quarter of that of adults. This approach is consistent with (Gillespie et al., 2017). Because the opportunity cost of time proved to be similar across SA, NSW and Victorian metro regions, and regional areas, we collapsed time estimates into a single metro opportunity cost estimate and a single regional opportunity cost estimate, based on respondents' residential location.

Average vehicle cost per kilometres are based on standard Australian Taxation Office rates – which are approximately $0.75 per kilometre in 2010 and 2015. This figure includes vehicle depreciation and other costs in addition to fuel costs. An alternative approach would be to use fuel costs only, which would yield lower travel cost estimates, as in (Heagney et al., 2019). Average travel costs per trip per person are derived by sharing total vehicle costs pro-rata across the average number of persons reported travelling per trip per zone.

Day and overnight expenditure were based on survey data from a comprehensive survey of recreational expenditure by participants at 22 Recreational Water Facilities in Victoria in 2016-17 (Street Ryan, 2017). We assume similar per visit day expenditures in 2010 and 2015 as in 2016-17. Overnight expenditures (for accommodation) are derived by sharing accommodation costs pro-rata across the average number of people per trip per zone. Assumed expenditure per person per day trip was set at $18, and $55 per person per overnight per overnight trip, with overnight trip costs reflecting that camping and staying with friends account for more than 70% of overnight stays (Table 58).

Travelling and recreation activities consume time that people could be spent doing other things. This is known as the opportunity cost of time and is a real economic cost. In this GKP evaluation, the opportunity cost of time is estimated using median employee income for NSW, Victoria and South Australia. Consistent with earlier studies (Gillespie et al., 2017; Heagney et al., 2019), we assume the opportunity cost of time for 19–64-year-old travellers is 35% of the median employee income, and 8.75% for people 18 and under and 65 and over.

Consistent with the approach in (Gillespie et al., 2017; Heagney et al., 2019) we only include travel time to the site in opportunity costs. This makes our estimate of the opportunity cost of time relatively conservative.

Given the potential reporting bias in the Greater Sydney respondents discussed above, we include consumption expenditure results based on Greater Sydney respondents self-reported visitation incidence. For comparison, we also include consumption expenditure assuming the Greater Sydney population has the same levels of visitation as the Greater Melbourne population in 2010 and 2015. These results are shown as Greater Sydney=Greater Melbourne* (GS=GM*) in the Tables and Figures in this section.

Approach to producing the welfare value of recreation

The welfare value of recreation was also calculated for comparison. The welfare value is not a direct exchange and, as a result, sits separate from the ecosystem physical and monetary supply and use tables. The welfare value is presented here to demonstrate the potential gap between the value the market currently places on recreation and the benefits available from recreation for society.

The GKP recreation user survey completed for this evaluation provides the basis for estimating the consumer surplus from recreation directly. The uncertainty surrounding the Greater Sydney respondent data means that estimating consumer surplus from the respondent survey data may yield misleading results. As a result, the approach used in this application relies on value transfer.

There is a substantial body of research estimating consumer surplus (welfare) values from active and passive recreation, including in GKP. For this evaluation we estimate consumer surplus from visits using the low, middle and high range of estimates shown in Table 59. These values reflect:

- Recent work evaluating the economic value of tourism and recreation across the protected area network across all of NSW (Heagney et al., 2019). This evaluation is one of the largest studies of its kind undertaken to date, drawing on data from a stratified random phone-survey of more than 60,000 individuals for visits to any of the 728 protected areas within NSW. They estimate (1) an average consumer surplus of $31 per visit across all park assets ($AUD2015) (2) average consumer surplus of $90 per visit for the NSW population, which is the relevant population for comparison and (3) higher values for visits at higher profile parks ($330 per visit for NSW residents visiting Kosciusko National Park, $685 per visit for Royal National Park and $690 per visit for the Blue Mountains).
- Consumer surplus for recreation visits to Gunbower have been estimated in the order of $80 per person per visit (confidence interval $50-180 per trip), in $2020 (NCEconomics, 2020). Note this is per visit, not per day, and the evaluation relies on small sample data.

- Consumer surplus for recreation visits to Barmah Forest in 2005-07 were estimated in the of $130 per person per day (confidence interval $90-250), in $2007 (NCEconomics, 2020).

Given the potential reporting bias in the Greater Sydney respondents discussed above, we include consumption expenditure and consumer surplus results based on Greater Sydney respondents self-reported visitation incidence. For comparison, we also include consumption expenditure and consumer surplus assuming the Greater Sydney population has the same levels of visitation as the Greater Melbourne population in 2010 and 2015. These results are shown as Greater Sydney=Greater Melbourne* (GS=GM*) in the Tables and Figures in this section.

Table 58 Reported accommodation by overnight stay

	Gunbower	KP
Camping	64%	63%
Caravan	10%	8%
Hotel	11%	13%
Friends	9%	8%
Bed and breakfast	3%	3%
Own accommodation	3%	6%

Estimates

Estimates used to generate the accounting outputs in Table 66 are summarised below by zone.

Table 59 Expenditure and consumer surplus assumptions, 2010 and 2015

Variable		Assumption
Travel cost per km		$0.75 per kilometre
Day expenditure		$18 per person per full day
Overnight expenditure		$55 per person per overnight
Opportunity time cost per hour 19-64	NSW / VIC / SA metro median income	$8.90 / 8.42 / 8.29
	NSW / VIC / SA regional median income	$7.65 / 7.35 / 7.11
Opportunity time cost per hour not 19-64	NSW / VIC / SA metro median income	$2.22 / 2.11 / 2.07
	NSW / VIC / SA regional median income	$1.91 / 1.84 / 1.78
Consumer surplus per visit		$30/$90/$180

Table 60 Estimated expenditure by category, Gunbower 2015 ($AUD)

	Reason adjusted drive cost	Reason adjusted visit cost	Reason adjusted drive opportunity cost of time	Total
Total	**22,888,000**	**10,054,000**	**25,140,000**	**58,082,000**
Total (GS=GM*)	**8,682,000**	**7,018,000**	**11,379,000**	**27,079,000**
0-50km	87,000	203,000	298,000	588,000
50-250km	1,854,000	2,375,000	2,975,000	7,204,000
250-450km	170,000	179,000	322,000	671,000

	Reason adjusted drive cost	Reason adjusted visit cost	Reason adjusted drive opportunity cost of time	Total
450-650km	2,790,000	1,233,000	2,725,000	6,748,000
650-850km	16,057,000	5,408,000	16,735,000	38,200,000
850-1,050km	1,343,000	454,000	1,517,000	3,314,000
>1,050km	584,000	199,000	567,000	1,350,000

Table 61 Estimated expenditure by category, Gunbower 2010 ($AUD)

	Reason adjusted drive cost	Reason adjusted visit cost	Reason adjusted drive opportunity cost of time	Total
Total	**18,019,000**	**7,497,000**	**19,423,000**	**44,939,000**
Total (GS=GM*)	**6,024,000**	**4,532,000**	**7,563,000**	**18,119,000**
0-50km	44,000	102,000	149,000	295,000
50-250km	1,140,000	1,461,000	1,830,000	4,431,000
250-450km	38,000	40,000	72,000	150,000
450-650km	2,200,000	972,000	2,149,000	5,321,000
650-850km	13,131,000	4,423,000	13,686,000	31,240,000
850-1,050km	714,000	241,000	806,000	1,761,000
>1,050km	748,000	255,000	727,000	1,730,000

Table 62 Estimated expenditure by category, KP 2015 ($AUD)

	Reason adjusted drive cost	Reason adjusted visit cost	Reason adjusted drive opportunity cost of time	Total
Total	**9,765,000**	**5,467,000**	**11,139,000**	**26,371,000**
Total (GS=GM*)	**3,377,000**	**2,651,000**	**4,638,000**	**10,666,000**
0-50km	7,000	16,000	24,000	47,000
50-250km	513,000	871,000	999,000	2,383,000
250-450km	29,000	28,000	40,000	97,000
450-650km	1,262,000	407,000	1,344,000	3,013,000
650-850km	6,899,000	3,684,000	7,498,000	18,081,000
850-1,050km	690,000	319,000	909,000	1,918,000
>1,050km	363,000	139,000	323,000	825,000

Table 63 Estimated expenditure by category, KP 2010 ($AUD)

	Reason adjusted drive cost	Reason adjusted visit cost	Reason adjusted drive opportunity cost of time	Total
Total	**5,667,000**	**3,032,000**	**6,440,000**	**15,139,000**
Total (GS=GM*)	**2,249,000**	**1,507,000**	**2,949,000**	**6,705,000**
0-50km	12,000	25,000	39,000	76,000
50-250km	258,000	438,000	502,000	1,198,000
250-450km	13,000	13,000	19,000	45,000
450-650km	1,395,000	451,000	1,486,000	3,332,000
650-850km	3,673,000	1,961,000	3,992,000	9,626,000
850-1,050km	283,000	131,000	374,000	788,000
>1,050km	30,000	11,000	27,000	68,000

Table 64 Consumer surplus by zone, 2015

distance	Gunbower			KP		
	Lower	**Mid**	**Upper**	**Lower**	**Mid**	**Upper**
Total	**10,392,000**	**31,174,000**	**62,346,000**	**4,194,000**	**12,579,000**	**25,159,000**
Total (GS=GM*)	**7,693,000**	**23,077,000**	**46,153,000**	**2,747,000**	**8,239,000**	**16,479,000**
0-50km	505,000	1,514,000	3,027,000	43,000	128,000	257,000
50-250km	2,790,000	8,370,000	16,740,000	975,000	2,925,000	5,850,000
250-450km	247,000	740,000	1,481,000	31,000	93,000	186,000
450-650km	986,000	2,958,000	5,917,000	470,000	1,410,000	2,820,000
650-850km	5,489,000	16,467,000	32,933,000	2,422,000	7,265,000	14,530,000
GS=GM	281,000	843,000	1,685,000	193,000	579,000	1,157,000
850-1,050km	94,000	282,000	563,000	60,000	179,000	359,000

Table 65 Consumer surplus by zone, 2010

distance	Gunbower			KP		
	Lower	**Mid**	**Upper**	**Lower**	**Mid**	**Upper**
Total	**7,563,000**	**22,687,000**	**45,375,000**	**2,465,000**	**7,398,000**	**14,795,000**
Total (GS=GM*)	**4,791,000**	**14,370,000**	**28,743,000**	**1,666,000**	**5,001,000**	**10,000,000**
0-50km	254,000	761,000	1,522,000	67,000	202,000	404,000
50-250km	1,717,000	5,150,000	10,301,000	490,000	1,471,000	2,941,000
250-450km	56,000	167,000	335,000	15,000	45,000	89,000
450-650km	778,000	2,333,000	4,666,000	520,000	1,559,000	3,119,000
650-850km	4,489,000	13,467,000	26,933,000	1,289,000	3,868,000	7,736,000
GS=GM	149,000	448,000	896,000	79,000	238,000	476,000
850-1,050km	120,000	361,000	722,000	5,000	15,000	30,000

4.10.3 Areas for Improvement

The approach applied to estimate recreation use and value improves on earlier approaches in several ways:

- supply and use accounts are based on recreation days from visitation, which is a more accurate estimate of actual use than visitors.
- The approach accounts for multi-purpose trips. Using an importance scale for multi-purpose trips provides a robust approach to attribute consumption expenditure to GKP versus other trip objectives.
- Including the opportunity cost of travel time consistent with approaches for including final consumption expenditure in national accounts and the payment of wages and salaries in kind.

The key areas for improvement relate to the recreation survey. For this evaluation, survey respondents were asked about visits to GKP in 2015 and 2010. This requires the ability to accurately recall trip details, which introduces the likelihood of recall error.

Given the priority of GKP as an Icon site, recreation at GKP should be more comprehensively monitored in the future. This would involve undertaking systematic surveying of visitors, with travel cost method applications in mind. The survey developed for the current GKP evaluation could be used as the basis for these future evaluations. The survey could gather information on the drivers of visitation to support linking visitation and site use to the ecosystem-level data.

In NSW, Parks Victoria completes biennial surveys and face to face interviews known as the Visitor Number Monitor (VNM) as part of their integrated research program. To develop a standard recreation and visitation survey approach in Victoria, DAWE and Victorian CMAs partner with Parks Victoria to gather information through the VNM.

4.10.4 Accounting outputs

A recreation-related services physical supply and use table (Table 66) and monetary supply and use table (Table 67) as developed for the accounting area. Supply and use tables show the relationship between recreation supplied, the GKP ecosystem, and households as the user. This approach aligns with the SEEA framework (UNCEEA, 2021b). Table 66 and Table 67 estimates are based on the assumption that Greater Sydney visitation approximates Greater Melbourne visitation. This yields more conservative estimates.

In 2010, total visit days to Gunbower and KP are estimated at 211,000 (Table 66). Note this is total visit days, not visits, and that Table 54 includes total visits. Around three quarters of total visit days are in Gunbower NP. Average visitor days per visit are around 1.35 visitor days for Gunbower NP and around 1.2 visitor days for KP.

In 2015, total visit days to Gunbower and KP are estimated at 340,000 (Table 66). Note this is total visit days, not visits, and that Table 54 includes total visits. Around three quarters of total visit days are in Gunbower NP. Average visitor days per visit are around 1.55 visitor days for Gunbower NP and around 1.2 visitor days for KP.

Consumption expenditure in Table 67 includes drive and visit consumption expenditure totals, and excludes opportunity costs. Consistent with Table 66, the consumption expenditure assume that visitation from Greater Sydney is at the same level as Greater Melbourne. This yields a more conservative estimate than using the Greater Sydney expenditure estimates, which are shown in Table 60 to Table 63.

In 2010, consumption expenditure attributable to Gunbower and KP are estimated at $14.3 million (Table 66). Around three quarters of total consumption expenditure is attributable to Gunbower NP. In 2015, consumption expenditure attributable to Gunbower and KP are estimated at $21.7 million (Table 67). Around 72 percent of total consumption expenditure is again attributable to Gunbower NP.

Table 60 to Table 63 show that drive and visit consumption expenditure totals in the order of $21-48 million in 2015 for Gunbower and KP combined, and $13-34 million in 2010. The lower of the annual figures assume that visitation from Greater Sydney is at the same level as Greater Melbourne. The higher figure assumes the reported visit incidence from the survey is accurate.

Table 64 to Table 65 show that consumer surplus from GKP recreation $10-87 million in 2015, with a mid-range estimate in the order of $31-44 million. Estimates for 2010 are that consumer surplus from GKP recreation ranges between $6-70 million in 2010, with a mid-range estimate in the order of $19-30 million. The lower of the annual consumer surplus figures assume that visitation from Greater Sydney is at the same level as Greater Melbourne. The higher figures assume the reported visit incidence from the survey is accurate.

Using mid-range estimate data from Table 64 and 65, and applying the same assumption that informed the physical and (exchange-based) monetary flows (i.e. Greater Sydney = Greater Melbourne), the monetary supply and use of welfare-based values (using consumer surplus) increases from $19.3M in 2010 to $31.3M in 2015.

These consumer surplus estimates for Gunbower in 2015 are consistent with previous estimates that estimate mid-range consumer surplus from Gunbower recreation in the order of $36 million in 2018 (NCEconomics, 2020). While the estimates are not directly comparable because they are estimated using different approaches, the similarity of estimates does provide some basis for cross-verification.

Table 66 Recreation-related services, physical supply and use table, GKP, 2010 and 2015

Supply /Use	Units	Economic units			Ecosystem type: Gunbower							Ecosystem type: Koondrook - Perricoota						
		Household	Government	Industries	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Total	Fire-intolerant *Callitris* woodlands	Inland floodplain eucalypt forests and woodlands	Wetlands	Cultivated areas	Re-sprouter temperate and subtropical eucalypt woodlands	Lowland Streams	Total
2010																		
Supply	Visit days				-	-	-	-	-	-	156,000	-	-	-	-	-	-	55,000
Use	Visit days	211,000		-														
2015																		
Supply	Visit days				-	-	-	-	-	-	252,000	-	-	-	-	-	-	88,000
Use	Visit days	340,000		-														

Note: '–' = 0, Confidence in data is moderate.

Table 67 Recreation-related services, monetary supply and use summary table, GKP, 2010 and 2015

		Economic units			Ecosystem type													
					Gunbower							Koondrook - Perricoota						
Supply/Use	**Units**	**Household**	**Government**	**Industries**	**Fire-intolerant *Callitris* woodlands**	**Inland floodplain eucalypt forests and woodlands**	**Wetlands**	**Cultivated areas**	**Re-sprouter temperate and subtropical eucalypt**	**Lowland Streams**	**Total**	**Fire-intolerant *Callitris* woodlands**	**Inland floodplain eucalypt forests and woodlands**	**Wetlands**	**Cultivated areas**	**Re-sprouter temperate and subtropical eucalypt**	**Lowland Streams**	**Total**
2010																		
Supply	$AUD				–	–	–	–	–	–	10,556,000	–	–	–	–	–	–	3,756,000
Use	$AUD	14,312,000	–	–														
2015																		
Supply	$AUD				–	–	–	–	–	–	15,700,000	–	–	–	–	–	–	6,028,000
Use	$AUD	21,728,000	–	–														

Note: '–' = 0, Confidence in estimates is moderate.

5 Quality Declaration

The accounts in this document reflect the concepts and definitions of the United Nations System of Environmental-Economic Accounting. In addition, to respond to the policy and analytical requirements of this project some complementary monetary values have been included that go beyond the scope of monetary valuation based on exchange values in the SEEA EA. Specifically, non-use values relating to ecosystem and species appreciation have been estimated and, for timber provisioning, recreation and the carbon sequestration component of global climate regulation services, welfare values have been derived.

Non-use values are excluded from the scope of the SEEA EA because they are not associated with a transaction between an ecosystem and people that is required for treatment as an ecosystem service in the SEEA EA. Welfare values differ from exchange values in large part because the former include measures of consumer surplus which the latter do not.

Further, while conceptually aligned with the SEEA EA, the approach used for measuring condition differs from the three-stage approach described in the SEEA EA Chapter 5. While stage 1 and stage 3 condition accounts are presented, we did not derive values for individual characteristics relative to reference levels (stage 2). In the future, when methods and data are further advanced it would be expected that the estimates in this report would also change.

6 Glossary

TERM	DEFINITION
Archetype model	conceptual model that describes the endogenous disturbance dynamics and ecosystem expressions that characterise ecosystems with integrity. These models are not operational and cannot be directly or solely used for measurement or mapping but provide a template for reference and modified states in state and transition models. (Richards et al., 2020)
Attribute	see 'ecosystem attributes'
Australian Ecosystem Models Framework	a standardised approach to collate, synthesise and summarise scientific knowledge on ecosystem dynamics in a set of conceptual models. These models describe the dynamic characteristics and drivers of Australian ecosystems in reference and modified states, as defined by (Richards et al., 2020).
Biodiversity	the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems (CBD, 1992)
Biome	a biotic community finding its expression at large geographic scales, shaped by climatic factors and characterised by physiognomy and functional aspects, rather than by species or life-form composition (Mucina, 2019); (UNCEEA, 2021b)
Community-level biodiversity	consideration of biodiversity for an assemblage of species within a taxonomic group at a location
Compositional similarity	the similarity in the assemblages of species occurring in different locations. In the present study, compositional similarity is considered in terms of pairs of locations.
Conceptual model	abstraction of reality that uses descriptions of system parts and their interactions to condense complex systems and processes into a format that allows more general understanding (BoM, 2016; Tilden et al., 2012). In ecology, they offer a flexible and simple way to summarise and communicate current understanding of ecosystem behaviour and enable identification of knowledge gaps. Conceptual models can also be used to explain historical ecosystem changes and help to predict future changes (Vankat, 2013). By removing complex details, conceptual models may assist in the discovery of patterns and the development of generalised characterisations of systems.
Disturbance	discrete event (in both space and time) that resets an ecosystem; that is, it disrupts ecosystem, community or population structure and changes resources, substrate availability or the physical environment (Hobbs & Huenneke,

	1992; White & Pickett, 1985). Disturbances are described by a regime, including frequency, intensity, duration, extent and timing. In contrast, a perturbation is 'any change in a parameter (state variable) that defines a system; that is, a departure (explicitly defined) from a normal state, behaviour, or trajectory (also explicitly defined)' (White & Pickett, 1985 p.5). While the terms 'disturbance' and 'perturbation' are sometimes used interchangeably, we will use the term 'disturbance' to denote a causal event that is temporary and localised, while terms like 'perturbation' or 'stress' are restricted to describing an effect or response of an ecosystem to a disturbance event or other ecological process (Rykiel, 1985). Thus, climate change may be a stress to biodiversity, but droughts, which are predicted to increase in frequency and duration under climate change in many regions (Lemoine et al., 2016; Trenberth et al., 2014), are the potential sources of disturbance (Dornelas, 2010).
Driver	a factor that causes a particular phenomenon to happen or develop. In the case of the Australian Ecosystem Models Framework (Richards et al., 2020), a driver may be a management action or a threatening process that results in a transition between ecosystem states.
Ecological integrity	an ecosystem's capacity to maintain composition, structure, functioning and self-organisation over time using processes and elements characteristic for its ecoregion and within a natural range of variability (UNCEEA, 2021b) (compare 'ecosystem integrity')
Ecosystem	a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (CBD, 1992)
Ecosystem accounting area	the geographical territory for which an ecosystem account is compiled (UNCEEA, 2021b)
Ecosystem asset	a contiguous space of a specific ecosystem type characterized by a distinct set of biotic and abiotic components and their interactions (UNCEEA, 2021b)
Ecosystem attributes	the biotic and abiotic properties and functions of an ecosystem (grouped into physical conditions, species composition, community structure, ecosystem function and external exchanges) (McDonald et al., 2016) 'Ecosystem attributes' are equivalent to 'ecosystem characteristics' in the SEEA-EA standard (UNCEEA, 2021b).
Ecosystem capacity	the ability of an ecosystem to generate an ecosystem service under current ecosystem condition, management and uses, at the highest yield or use level that does not negatively affect the future supply of the same or other ecosystem services from that ecosystem (UNCEEA, 2021b)
Ecosystem characteristic	a system property of the ecosystem and its major abiotic and biotic components (water, soil, topography, vegetation,

	biomass, habitat and species) with examples of characteristics including vegetation type, water quality and soil type (UNCEEA, 2021b)
Ecosystem condition	the quality of an ecosystem measured in terms of its abiotic and biotic characteristics (UNCEEA, 2021b) In the AusEcoModels Framework (Richards et al., 2020), ecosystem condition is a measure of ecosystem integrity including the capacity of ecosystem states to maintain biodiversity and ecosystem flows and connections. In the context of state and transition models it is defined as the departure of each ecosystem state from the reference state. The Habitat Condition Assessment System provides a condition score that represents the capacity of an area to provide the structures and functions necessary for the persistence of all species naturally expected to occur in that area if it were in an intact (or reference) state, and is calculated using departure from multiple locations in reference state (Williams et al., 2021).
Ecosystem condition indicator	rescaled version of ecosystem condition variables (UNCEEA, 2021b)
Ecosystem condition characteristic	an ecosystem characteristic that is relevant for the assessment of ecosystem condition (UNCEEA, 2021b)
Ecosystem condition typology	a hierarchical typology for organising data on ecosystem condition characteristics (UNCEEA, 2021b)
Ecosystem condition variable	a quantitative metric describing individual characteristics of an ecosystem asset (UNCEEA, 2021b)
Ecosystem conversion	situation in which, for a given location, there is a change in ecosystem type involving a distinct and persistent change in the ecological structure, composition and function which, in turn, is reflected in the supply of a different set of ecosystem services (UNCEEA, 2021b)
Ecosystem dynamics	ecosystem patterns and processes that are driven by disturbance and recovery (Battisti et al., 2016). Different stages of ecosystems along pathways of disturbance and recovery are termed 'ecosystem expressions'.
Ecosystem expression	a distinct, recognisable node within both the reference state and modified states of ecosystems. Each ecosystem state is dynamic and contains one to several ecosystem expressions, which have different ecosystem characteristics resulting from disturbance and biomass recovery processes.
Ecosystem extent	the size of an ecosystem asset in terms of spatial area (UNCEEA, 2021b)
Ecosystem integrity	the level of intactness, completeness and integration in the structure, composition and function of an ecosystem with respect to the persistence of biodiversity. If a system is able to maintain its organisation (function and structure) over time in response to environmental disturbance cycles then it is said to have integrity (Kandziora et al., 2013; Kay, 1991).

	(compare 'ecological integrity')
Ecosystem services	the contributions of ecosystems to the benefits that are used in economic and other human activity (UNCEEA, 2021b)
Ecosystem state	the manifestation of an ecosystem at a particular point in space and time
Ecosystem type	In the SEEA-EA standard: an ecosystem type reflects a distinct set of abiotic and biotic components and their interactions (UNCEEA, 2021b). In AusEcoModels Framework: a unit of an ecosystem classification defined by the ecosystem characteristics (e.g. facets of structure, function, composition) that characterise the reference state for a given scale of organisation, for example defined by its discrete disturbance and recovery dynamic (Kay, 1991; Richards et al., 2020). An ecosystem type, once defined, may be spatially identified and mapped as a geographic unit.
Endogenous disturbance	a disturbance internal to an ecosystem (Rogers, 1996) that maintains ecosystem integrity. They include fire, drought, floods, cyclones, storms, erosive and depositional processes, heatwaves, cold snaps, chemical intrusion and biotic outbreaks. They characterise ecosystems in the Australian environment prior to processes that have driven the homogenisation of ecosystems (an era termed the 'Homogenocene') and may be driven by anthropogenic (e.g. ecological fire management) or non-anthropogenic (climate) processes.
Environmental water	share of water that can be used to achieve environmental outcomes (MDBA, 2012)
Exogenous disturbance	a disturbance external to an ecosystem (Rogers, 1996) that can trigger transitions from the reference to modified states (with lower ecosystem integrity) by transforming transient disturbances into persistent disturbances (e.g. switching from macropod grazing regimes to continuous cattle grazing), introducing new disturbances that result in chronic stress on an ecosystem (e.g. habitat fragmentation from land clearing) or suppressing important disturbance events (e.g. fire suppression near urban areas) (Suding & Hobbs, 2009). Exogenous disturbances are driven by anthropogenic actions associated with the Homogenocene.
Habitat Condition Assessment System	a method to remotely assess and map the generalised condition of natural habitat for terrestrial native biodiversity at a location against a reference condition derived from the dynamics of the most intact examples of native vegetation / ecosystems across contemporary Australia (Williams et al., 2021).
Homogenocene	an era within which the Earth is experiencing rapid loss of its unique biological and cultural heritage, whilst its ecosystems and cultures are being increasingly homogenised (Curnutt, 2000; Samways, 1999). The international start date for this era is identified as 1493, when germs, plants, animals and

	cultures began to be exchanged around the globe. Ecosystem homogenisation is in part attributed to transference of common agricultural and invasive species around the globe, along with other drivers such as land clearing. The onset and intensification of ecosystem homogenisation processes varies across continents and regions – in Australia, most notably since European colonisation and subsequent settlement history.
Integrity	see 'ecosystem integrity'
Land cover	the observed physical and biological cover of the Earth's surface, including natural vegetation and abiotic (non-living) surfaces (United Nations, 2014, para. 5.257)
Management action	deliberate action undertaken by people to alter aspects of an ecosystem, often resulting in the transition from one ecosystem state to another. One or more management actions may be part of an exogenous disturbance.
Modified state	an ecosystem state that is not in reference condition, due to exogenous disturbances. Modified states are dynamic, and change between ecosystem expressions resulting from interactions between endogenous and exogenous disturbances (e.g. natural flood events may shift expressions within a modified state in conjunction with managed environmental watering events).
Species Persistence	the ongoing maintenance of a species as viable populations over the long term
Potential extent of occurrence	the area contained within the shortest continuous imaginary boundary that can be drawn to encompass all the current known localities, as well as inferred occurrence and projected original occurrence of a species (Brooks et al., 2019)
Reference condition	the condition against which past, present and future ecosystem condition is compared to in order to measure relative change over time (UNCEEA, 2021b)
Reference disturbance	see 'endogenous disturbance'
Reference level	the value of a variable at the reference condition, against which it is meaningful to compare past, present or future measured values of the variable (UNCEEA, 2021b)
Reference state	the dynamic state of an ecosystem that has ecosystem integrity and is in reference condition. Archetype models are used as templates for the description of a reference state for a particular ecosystem type. Usually reference states refer to a local example of an ecosystem and contain more detailed quantitative information on ecosystem attributes and endogenous disturbance regimes, compared to the archetype model.
Species richness	the number of species occurring in a location, typically considered within a specific taxonomic group

Species-level biodiversity	consideration of biodiversity for each individual species separately
State and transition model	conceptual tool that describes the state of a particular ecosystem (which may vary, for example, from reference to degraded, in terms of ecosystem integrity), and the drivers or agents that cause transitions between states (Bestelmeyer et al., 2017; Stringham et al., 2003; Westoby et al., 1989). Transitions between states occur as a result of the introduction of new exogenous disturbance regimes, the transformation of transient disturbances into persistent disturbances, and/or changes to reference disturbance regimes (resulting in a shift to an exogenous disturbance), altering environmental conditions and resources available to constituent species. These changes may be directly caused by recent anthropogenic modification of local habitats (e.g. vegetation thinning or clearing, stock grazing, introduction of native or alien invasive species), or may result from recent and rapid climate change (i.e. an indirect anthropogenic driver). Transitions in state and transition models are difficult to reverse without application of intensive management, an extreme event or long timeframe (Bestelmeyer et al., 2017; Bestelmeyer et al., 2009), and are distinguished from pathways between different ecosystem expressions within a state, which often result from slow-acting but incremental successional processes (Rumpff et al., 2011).
Threatening process	a process that causes or may cause a transition from one ecosystem state to another, resulting in reduced ecosystem condition
Transition	change between ecosystem states
Umbrella class	group of archetype models in the AusEcoModels Framework (Richards et al., 2020) that is compatible with Major Vegetation Groups in the National Vegetation Information System (NVIS) (NVIS Technical Working Group, 2017)

7 Suite of reports and data for Gunbower-Koondrook-Perricoota Forest Icon Site

Cheesman J, Dawson L, May D, Eigenraam M, Obst C, McLeod R and Goff S (2021) *Technical report on physical and monetary supply and use accounts for the Gunbower-Koondrook-Perricoota Forest Icon Site.* A technical report from the Land and Ecosystem Accounts Project. Department of Agriculture, Water and the Environment, Australia. https://eea.environment.gov.au/gkp.

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Harwood TD, Richards AE, Williams KJ, Mokany K, Schmidt RK, Ware C, Ferrier S and Prober SM (2021a) *Assessing condition of ecosystem types at Gunbower-Koondrook-Perricoota Forest Icon Site*. A technical report for the Land and Ecosystem Accounts Project. CSIRO, Australia. https://doi.org/10.25919/a9b7-9y54.

Harwood TD, Richards AE, Schmidt RK, Ware C, Prober SM, Ferrier S, Lehmann E, McVicar T, Bakar S, Mokany K and Williams KJ (2021b) *Ecosystem condition for the Gunbower-Koondrook-Perricoota Forest Icon Site v03.04.2021*. A data collection from the Land and Ecosystem Accounts Project. CSIRO, Australia. https://data.csiro.au/collections/collection/CIcsiro:47946.

McLeod R, Eigenraam M, Schmidt RK, May D, Cheesman J, Dawson L, Richards AE, Ferrier S, Goff S, Harwood T, Mokany K, Obst C and Prober SM (2021a) *Experimental ecosystem accounts for the Gunbower-Koondrook-Perricoota Forest Icon Site*. A report from the Land and Ecosystem Accounts Project. Department of Agriculture, Water and the Environment, Australia. https://eea.environment.gov.au/gkp.

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