Accounting for the ecosystem service of climate regulation: case study from Australia

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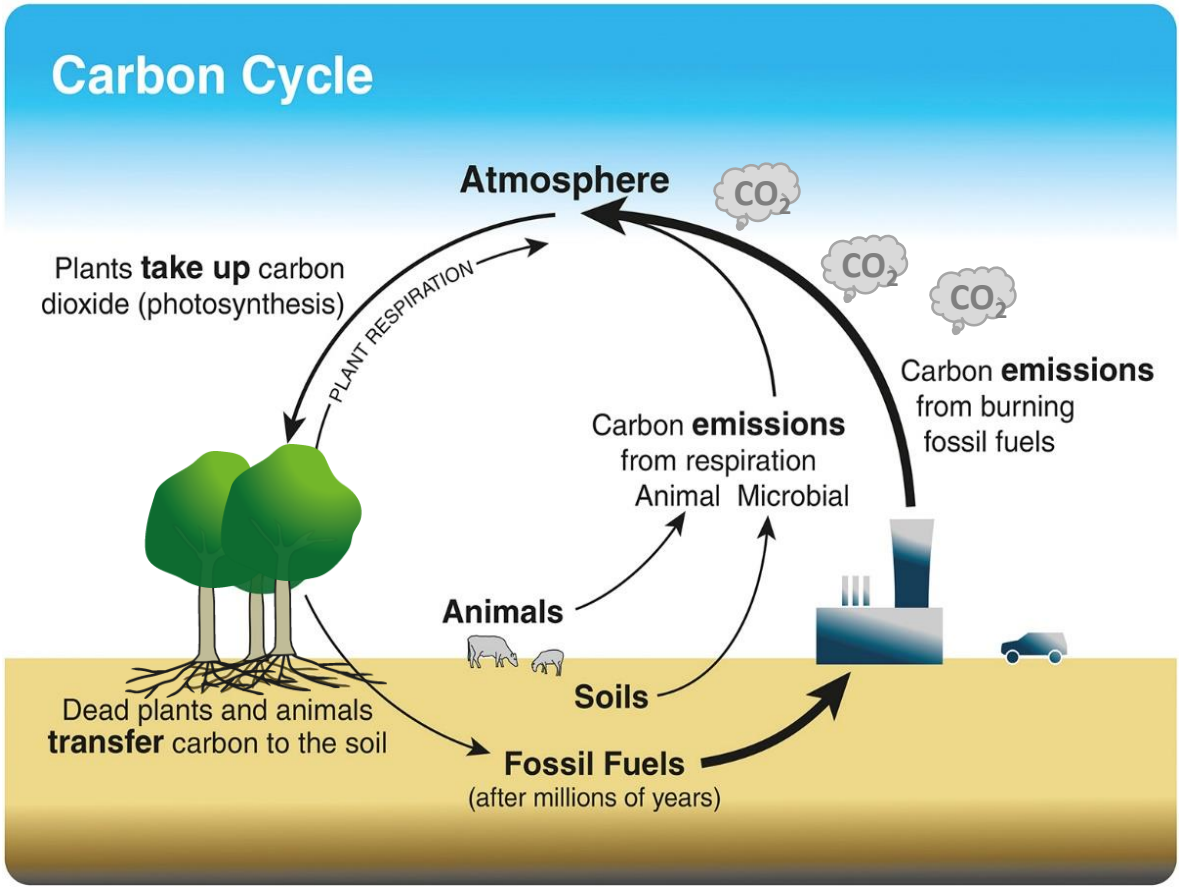
Ecosystem service of global climate regulation

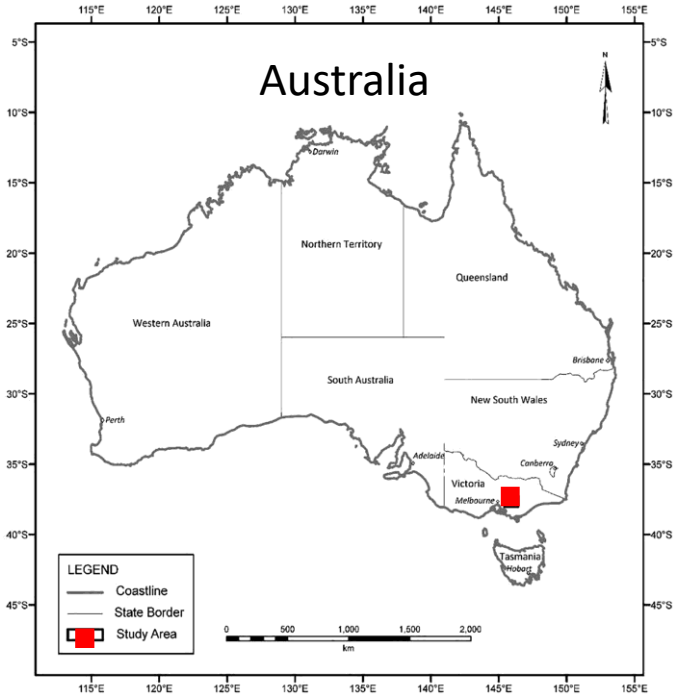
The ecosystem service of global climate regulation is the ecosystem contribution to the regulation of the concentration of greenhouse gases in the atmosphere, mainly through the retention of carbon in ecosystems.

- Carbon stored in ecosystems has a value represented as avoided damages.
- The value of the stored carbon is dependent on the condition of the ecosystem, which determines the longevity, stability and resilience of the carbon stock.
- The natural reference ecosystem condition should be used as the baseline.



Rationale for developing ecosystem accounts in the Central Highlands of Victoria, Australia

Industries dependent on ecosystem services from the Central Highlands region

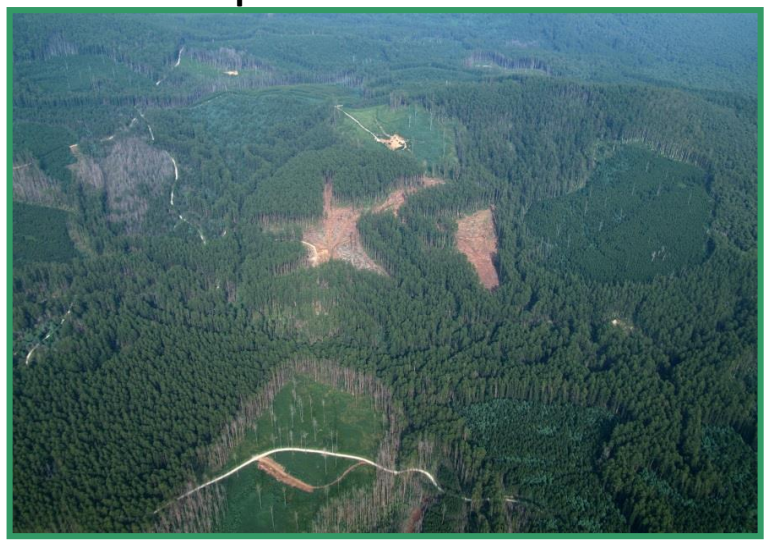


[Keith H. et al. 2017. Experimental ecosystem accounts for the Central Highlands of Victoria.]
[Keith H. et al. 2017 *Nature Ecology and Evolution* DOI: 10.1038/s41559-017-0309-1]

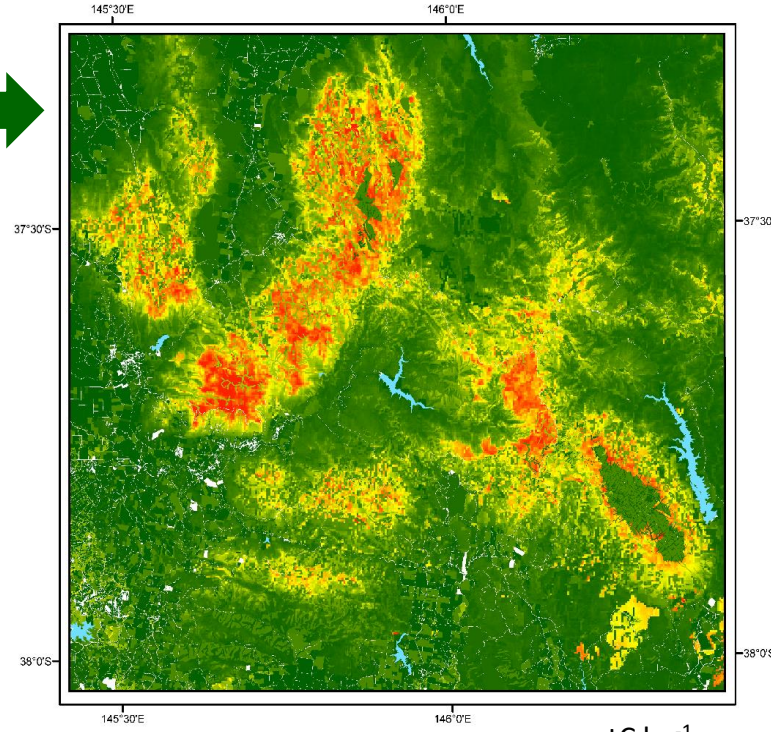
Data input to derive a spatial carbon map

Tree measurements

Landscape distribution of forests

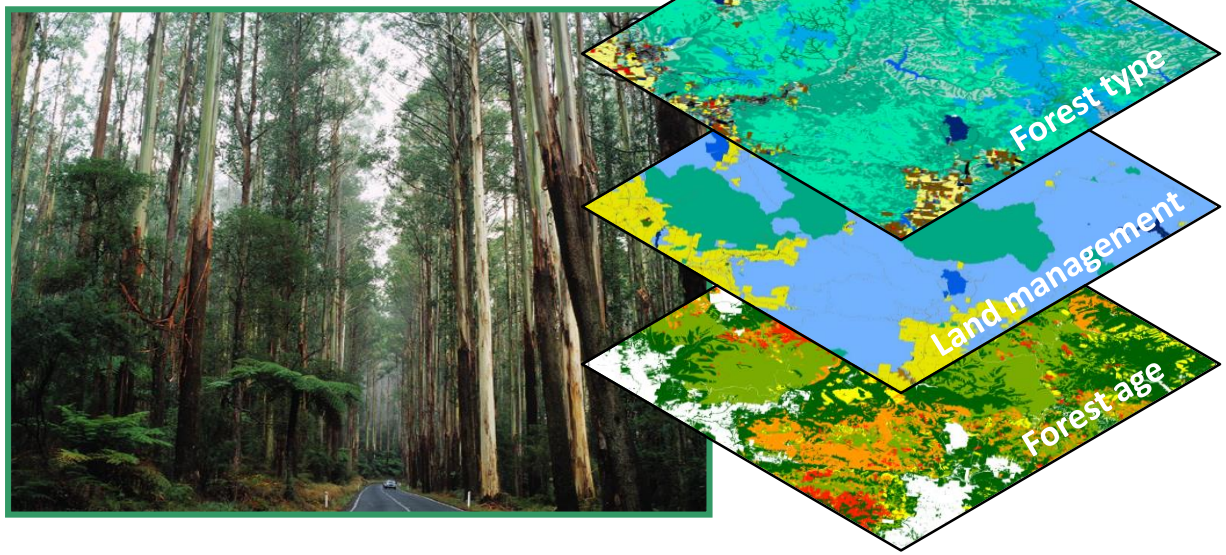


Spatial distribution of carbon stock density



Spatial landscape characteristics

Stand dynamics related to disturbance regimes



tC ha^{-1}

20.4 low
150
300
450
600
800
1100
1500 high
water body

Keith et al. 2009 *Agricultural and Forest Meteorology* 149: 535 - 558

Keith et al. 2010 *Global Change Biology* 16: 2671 - 2989

Keith et al. 2014 *Ecosphere* 5(6):75 doi: 10.1890/ES14-00051.1

Keith et al. 2014 PLoS ONE 9(9) e107126

Carbon stock account

	1991-95	1996-2000	2001-05	2006-10	2011-15
1. Total study area					
Opening stock (MtC)	119.05	124.47	129.82	135.09	137.85
Additions due to growth (MtC $5yrs^{-1}$)	7.96	8.48	8.89	8.91	10.00
Reductions due to fire (MtC $5yrs^{-1}$)	-0.07	-0.03	-0.05	-3.16	-0.06
Reductions due to harvesting (MtC $5yrs^{-1}$)	-2.47	-3.11	-3.58	-2.98	-2.07
Closing stock (MtC)	124.47	129.82	135.09	137.85	145.72
2.a) Area previously harvested					
Opening stock (MtC)	32.37	32.02	31.27	30.42	29.67
Additions due to growth (MtC $5yrs^{-1}$)	2.13	2.36	2.75	2.97	3.16
Reductions due to fire (MtC $5yrs^{-1}$)	-0.01	0.00	-0.02	-0.74	-0.01
Reductions due to harvesting (MtC $5yrs^{-1}$)	-2.47	-3.11	-3.58	-2.98	-2.07
Closing stock (MtC)	32.02	31.27	30.42	29.67	30.75
2.b) Area available for harvest					
Opening stock (MtC)	24.94	27.10	29.38	31.67	33.05
Additions due to growth (MtC $5yrs^{-1}$)	2.18	2.30	2.30	2.26	2.57
Reductions due to fire (MtC $5yrs^{-1}$)	-0.03	-0.02	-0.01	-0.88	-0.02
Reductions due to harvesting (MtC $5yrs^{-1}$)	0.00	0.00	0.00	0.00	0.00
Closing stock (MtC)	27.10	29.38	31.67	33.05	35.58
2.c) Area unavailable for harvest					
Opening stock (MtC)	61.74	65.35	69.17	72.99	75.13
Additions due to growth (MtC $5yrs^{-1}$)	3.65	3.83	3.84	3.68	4.27
Reductions due to fire (MtC $5yrs^{-1}$)	-0.03	-0.01	-0.01	-1.54	-0.02
Reductions due to harvesting (MtC $5yrs^{-1}$)	0.00	0.00	0.00	0.00	0.00
Closing stock (MtC)	65.35	69.17	72.99	75.13	79.38

[Keith et al. 2019 *Environmental Science and Policy* 93: 189 – 199]

PHYSICAL SUPPLY

	Economic Units									Environment Units								
										Biosphere								
	Agriculture, Forestry & Fisheries	Wood & paper product manufacturing	Other Industries (construction)	Households	Waste management	Energy	Government*	Inventory	Imports	Protected native forest	Woodland/ Shrubland	Harvested native forest	Hardwood plantation	Softwood plantation	Crops and horticulture	Grassland	Total biosphere	Atmosphere	TOTAL SUPPLY
Ecosystem Services																			
Carbon sequestration										1.368		0.632	0.116	0.008			2.124		2.124
Carbon storage										111.570	0.322	30.210	4.258	0.577	0.037	0.211	147.185		147.185
Carbon sink																		0.796	0.796
Products																			
Sawlogs-native forest	*0.050*	*0.018*	*0.018*	*0.005*				*0.035*											*0.126*
- plantation hardwood	*0.002*	*0.001*	*0.001*	*0.003*															*0.007*
- plantation softwood	*0.031*	*0.022*	*0.022*	*0.0002*															*0.075*
Total Logs	0.083	0.041	0.041	0.008				0.035											0.209
Pulp - native forest	*0.131*	*0.091*	*0.091*																*0.313*
- plantation hardwood	*0.085*	*0.060*	*0.060*																*0.205*
- plantation softwood	*0.017*	*0.012*	*0.012*																*0.041*
Total Pulp	0.233	0.163	0.163																0.559
Total Products	**0.316**	**0.204**	**0.204**	**0.008**				**0.035**											**0.767**

PHYSICAL USE

	Economic Unit									Environment Units								
										Biosphere								
	Agriculture, Forestry & Fisheries	Wood & paper product manufacturing	Other Industries (construction)	Households	Waste management	Energy	Government*	Inventory	Imports	Protected native forest	Woodland/ Shrubland	Harvested native forest	Hardwood plantation	Softwood plantation	Crops and horticulture	Grasslands	Total biosphere	Atmosphere	TOTAL USE
Ecosystem Services																			
Carbon sequestration	0.756						1.368												**2.124**
Carbon storage	35.293						111.892												**147.185**
Carbon sink																			
Harvested forest (native + plantation)																			
- emissions from fire	*0.006*																		*0.006*
- emissions from harvesting	*0.479*																		*0.479*
- emissions from processing		*0.112*		*0.195*															*0.307*
Protected native forest																			
- emissions from fire							*0.004*												*0.004*
Total emissions	0.485	0.112		0.195			0.004												**0.796**
Products																			
Sawlogs-native forest		*0.050*	*0.018*	*0.018*	*0.005*														*0.092*
- plantation hardwood		*0.002*	*0.001*	*0.001*															*0.004*
- plantation softwood		*0.031*	*0.022*	*0.022*				*0.025*											*0.100*
Total Sawlogs		0.082																	0.082
Pulp - native forest		*0.131*	*0.091*	*0.091*															*0.312*
- plantation hardwood		*0.085*	*0.060*	*0.060*															*0.205*
- plantation softwood		*0.017*	*0.012*	*0.012*				*0.014*											*0.055*
Total Pulp		0.233																	0.233
Total Products		**0.316**	**0.204**	**0.204**	**0.005**			**0.039**											**0.767**

Valuation of climate regulation services

Carbon retention value

- Based on the amount of carbon stored in an ecosystem - recognizing that the retained carbon stocks represent a value as avoided damages.
- Monetary valuation as a service flow is represented as an annual annuity, with higher flows reflecting higher levels of the ecosystem service provided by a larger stock of carbon.
- The stock is multiplied by a carbon price and then transformed into an annual service flow by multiplying by a rate of return to create an annual annuity.
- **Carbon retention value = Carbon stock x carbon price x rate of return**
- Carbon price as the Social Cost of Carbon – the expected economic cost associated with damage due to climate change that results from the emissions from an additional 1 tCO_2 to the atmosphere, that is, the marginal impacts of climate change.
- Carbon price of $US 4.75 in 2015 (based on a country-level estimate for Australia for the Social Cost of Carbon in Ricke et al. 2018 and adjusted to a 2015 price)
- Rate of Return of 3% (based on the US National Academies of Science valuation 2017, which is consistent with the discount rate used for calculating SCC)

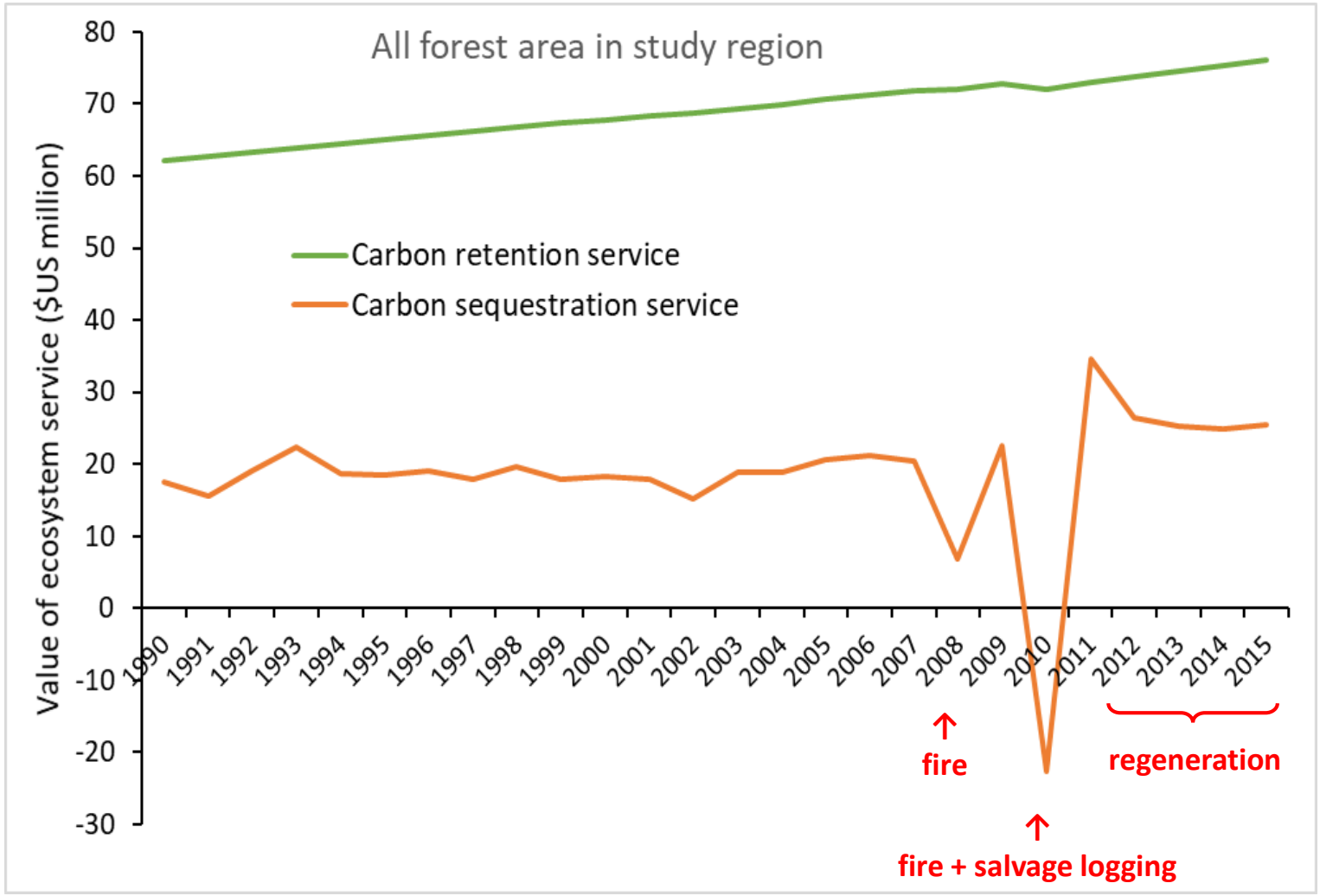
Carbon sequestration value

- Monetary valuation as a service flow based on the net annual carbon flow and a carbon price.
- Net annual carbon flow = net growth – losses from emissions
- **Carbon sequestration value = net annual carbon flow x carbon price**
- Carbon price: (1) Social Cost of Carbon of $US 4.75 in 2015

  (2) Australian Government Emissions Reduction Fund at $US 8.82 in 2015 (an exchange rate in a regulated market)

[Ricke et al. 2018 Country-level social cost of carbon. *Nature Climate Change* https://doi.org/10.1038/s41558-018-0282-y]
[National Academies of Science, Engineering and Medicine 2017. Valuing climate damages: updating estimation of the social cost of carbon dioxide. https://doi.org/10.17226/24651]

Carbon valuation for Central Highlands forests



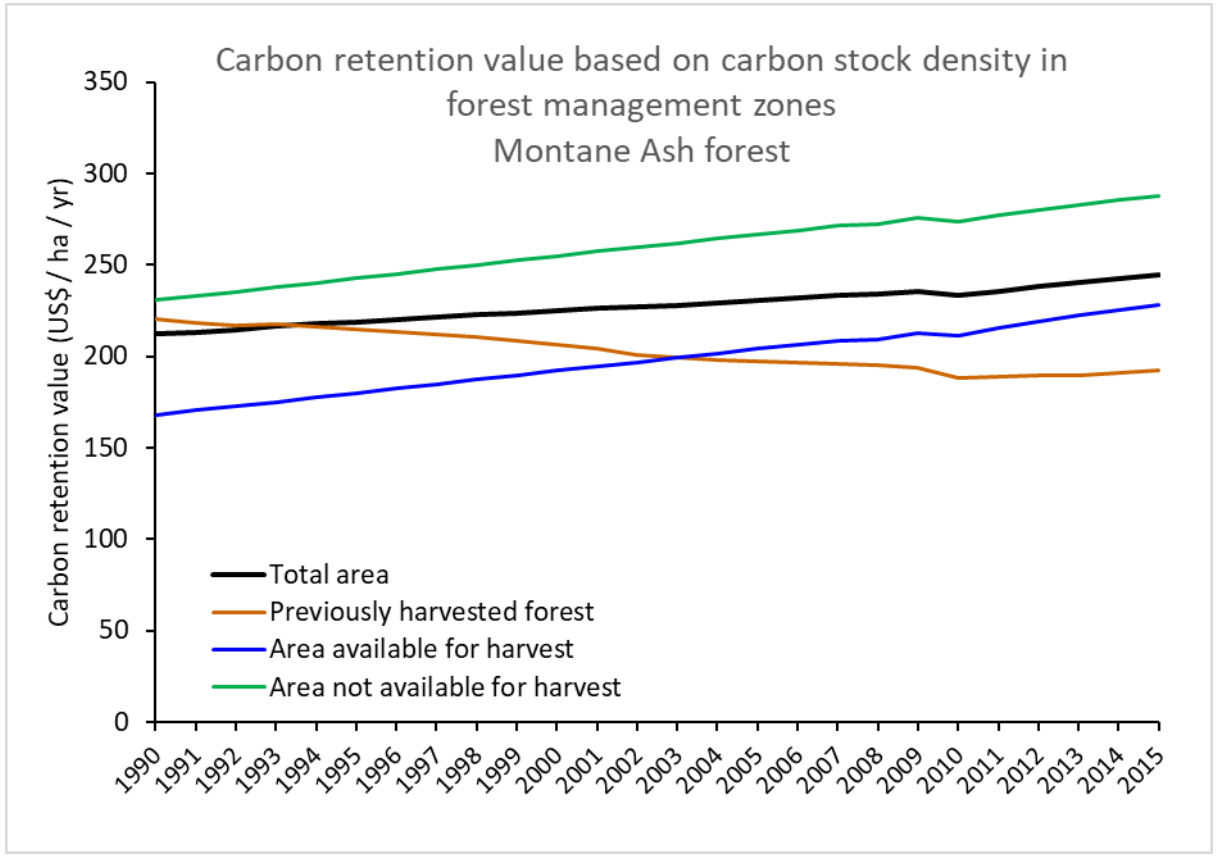
Differences between carbon retention and carbon sequestration

- The value of retention reflects the change in carbon stocks over time, and here represents the accumulated carbon in the ecosystem as growth > emissions over the whole region in the long term.
- The value of sequestration reflects the changes in stocks each year, and here represents annual fluctuations in rates of growth and emissions.

→ **Retention reflects storage of carbon in the biosphere**

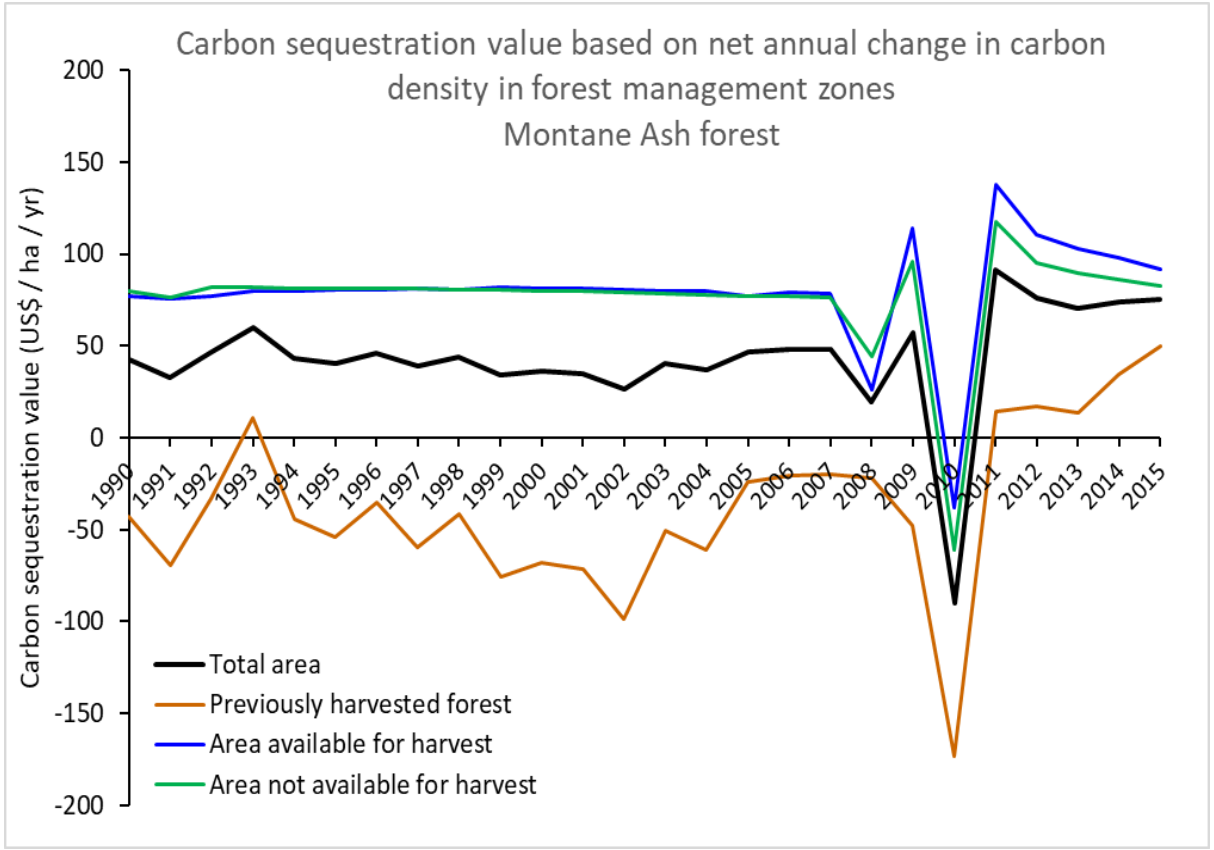
Comparison of forest management zones

Carbon stock density per ha averaged over the landscape within a single ecosystem type of Montane Ash forest



Carbon retention

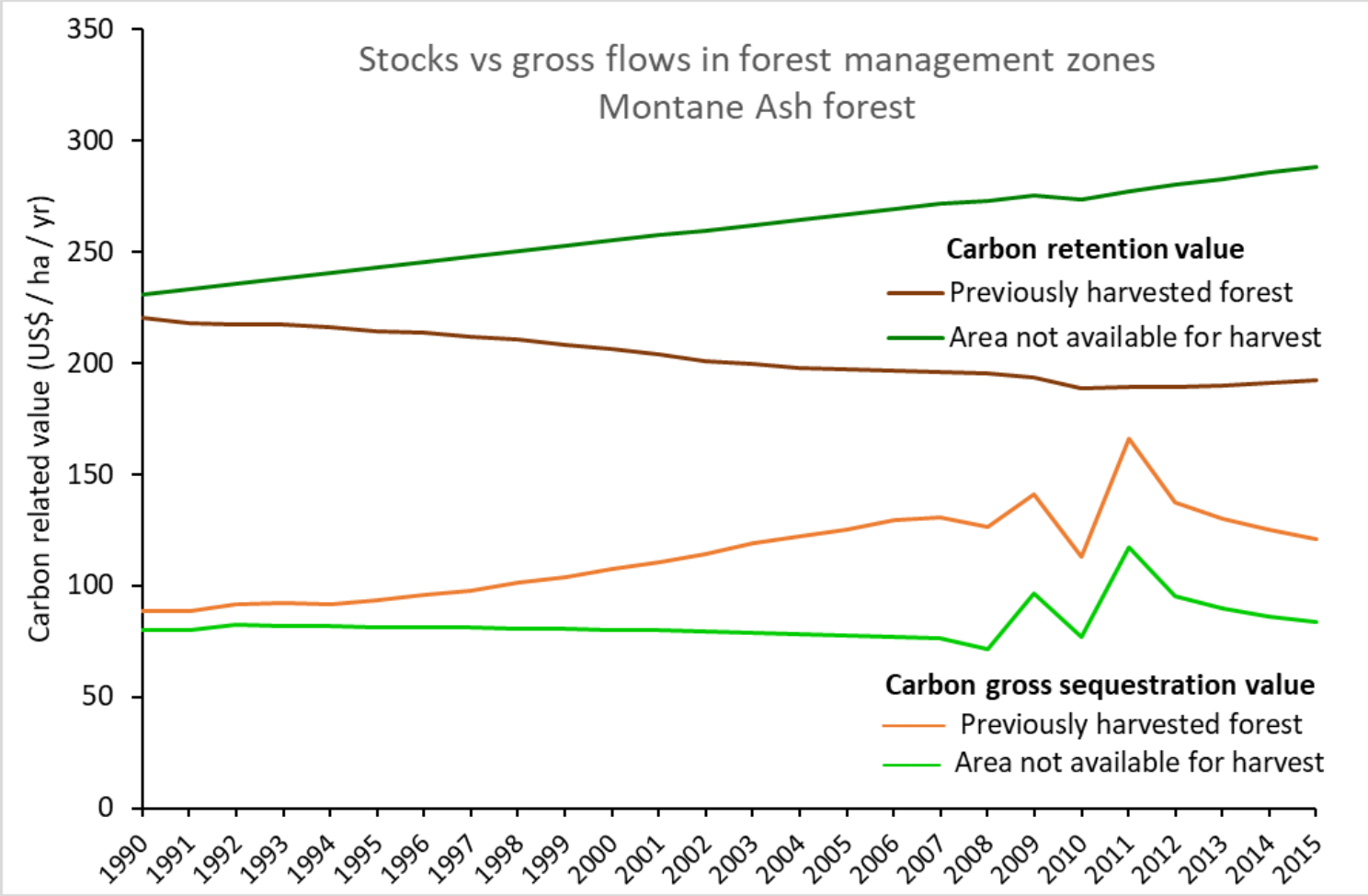
- Areas unharvested continue to accumulate carbon
- Harvested areas have declining carbon stocks
- Area previously harvested started with higher carbon stocks, presumably because the most productive forest was selected



Carbon sequestration

- Previously harvested area has a negative carbon balance most years
- Increase in the harvested area since the fire in 2009 is due to less harvesting as there is little mature green forest remaining

Carbon flows are not necessarily related to stocks



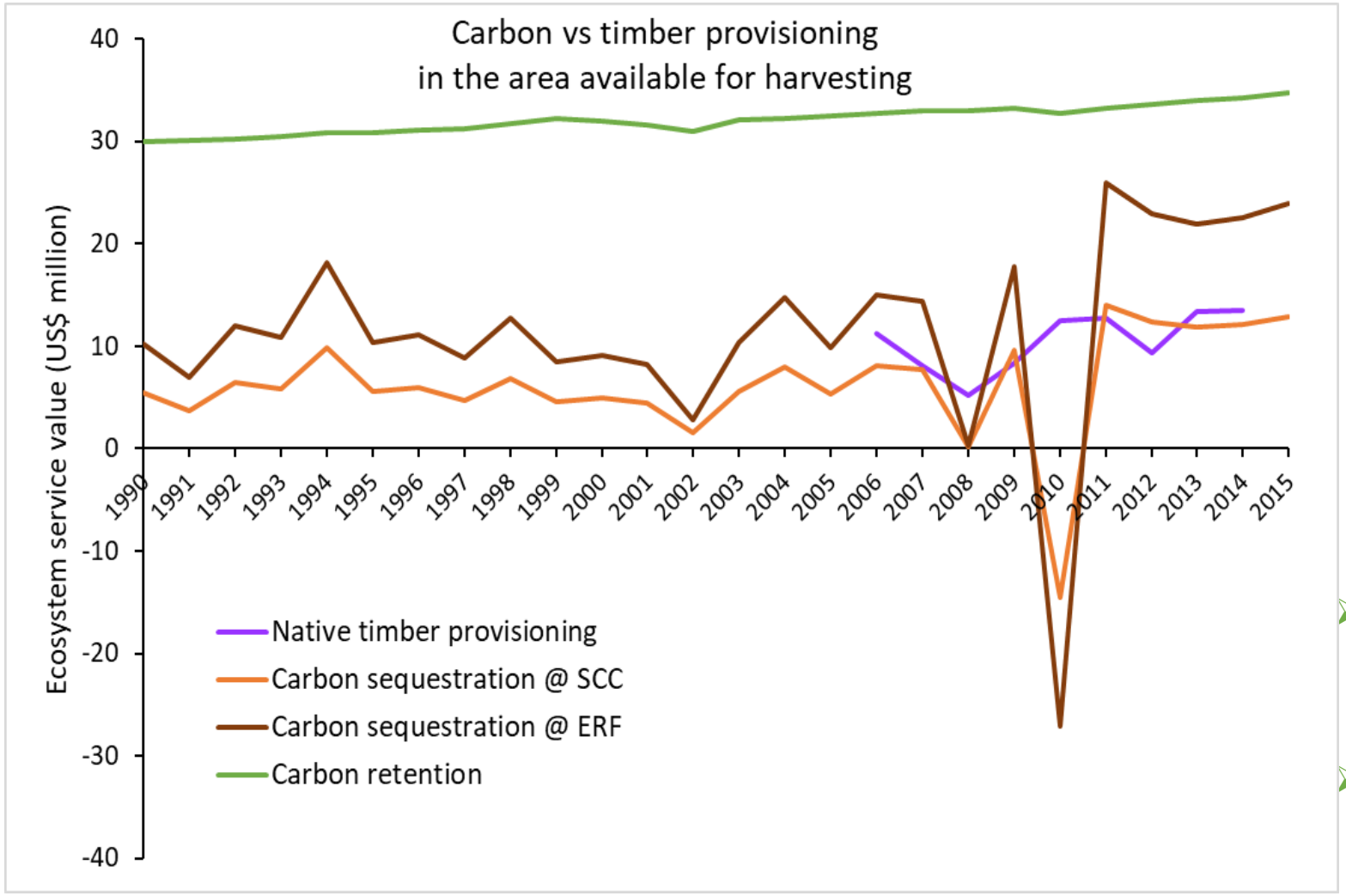
Carbon retention is based on stocks
Carbon gross sequestration is based on growth rate

- Previously harvested forest has higher sequestration as growth rates because trees, on average, are younger. But the carbon stock is lower and declining because the forest is younger.

- Area not harvested has older trees, slower growth rates, but higher carbon stocks.

➡ As a climate regulation service, the higher carbon stocks in the older forest have a greater value.

Comparing ecosystem services and prices



Ecosystem services

- Native timber provisioning service valued according to the stumpage price.
- Carbon sequestration valued at:
  - Social Cost of Carbon US$ 4.75 / tCO_2
  - Emissions Reduction Fund US$ 8.82 / tCO_2
- Carbon retention valued at the Social Cost of Carbon

Differences between carbon prices

- Various carbon prices are proposed and currently being applied nationally and internationally.
- The price shifts the total value of the ecosystem service up or down.

Policy signals from valuation of carbon retention

- The carbon retention value appears to be a realistic and practical method of valuation that gives the correct policy signals about the benefit of carbon stored in ecosystems.
- Recognising carbon stocks in ecosystems as the service that benefits humans aligns with the goal for climate change mitigation to increase the stock of carbon in the biosphere and reduce the stock of carbon in the atmosphere.
- The service of climate regulation depends on the amount of carbon stored, its longevity, stability and resilience, which are dependent on ecosystem integrity.
- Ecosystems that store high amounts of carbon in long-lived, stable forms provide a greater and more secure service e.g. old-growth temperate forests, mangroves and peatlands.
- An increase in carbon storage represents an ecosystem enhancement, which should be accounted as an investment.
- A reduction in the carbon stock represents a reduction in the service that can persist for a long time e.g. logging a forest.