

Australia's land carbon sinks in a changing climate

October 2026



Understanding the response of the land carbon cycle to climate and climate change is critical to the design and implementation of Australia's plans for Net-Zero and beyond.

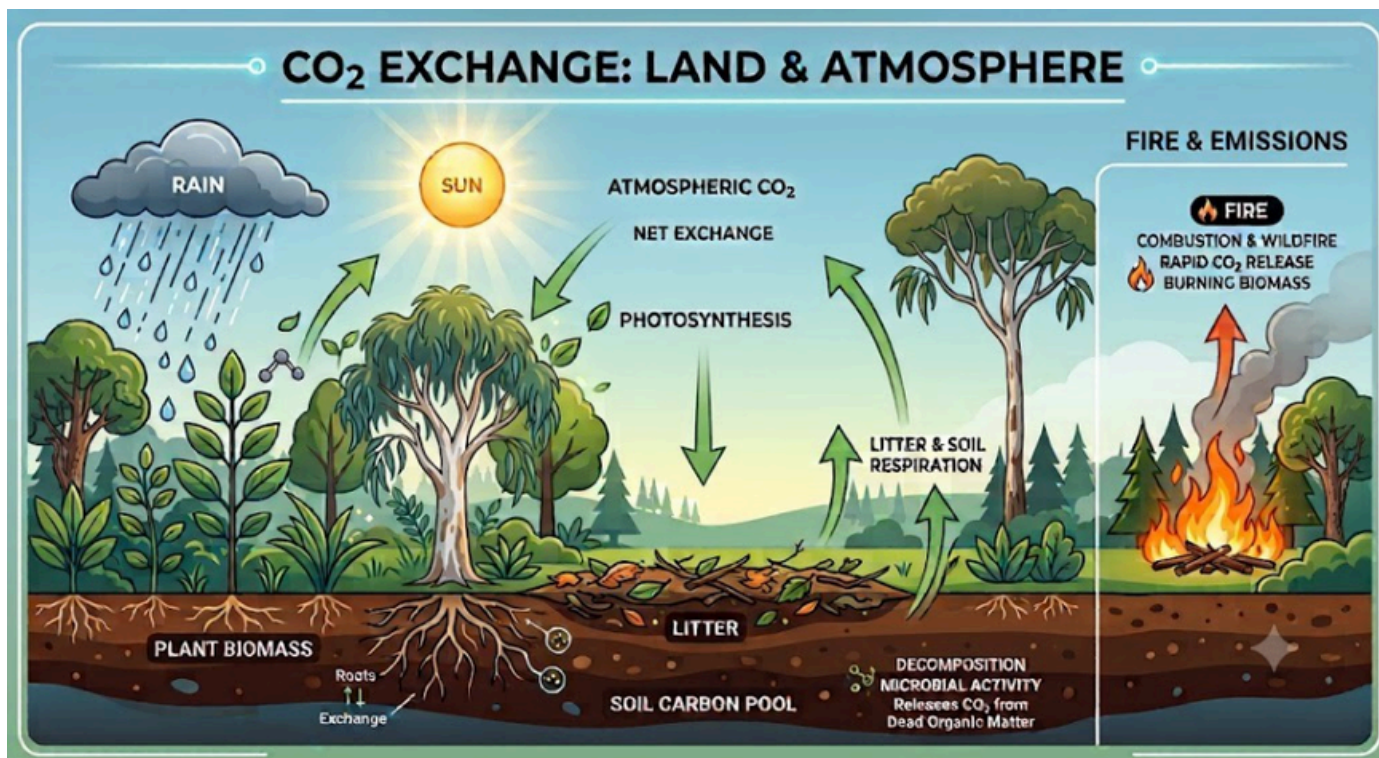
Globally, terrestrial ecosystems remove about 25% of all carbon dioxide emissions from human activities, slowing global warming¹. Australia's forests, savannas and grasslands are also doing their part in removing some of our carbon pollution, as part of natural processes and due to revegetation projects and efforts to restore degraded lands.

In addition to slowing down global warming, land carbon sinks are expected to play a larger role in the future: helping Australia to reach its Net-Zero emissions goal by 2050. Net-Zero requires a mitigation effort across the entire economy to reduce 'net' greenhouse gas emissions from the current 458 million tonnes of carbon dioxide equivalent per year ($\text{MtCO}_2\text{-e yr}^{-1}$) in 2025² to 'net' zero by 2050. The 'net' acknowledges that not all greenhouse gas emissions can become zero because of technical barriers or expense, particularly from some activities such as large industrial processes, the aviation sector, and livestock management. Instead, these 'residual' emissions will need to be offset with the direct removal of an equivalent amount of carbon dioxide from the atmosphere, mostly from nature-based solutions (e.g. revegetation, improved agriculture and forestry practices, and biofuels). Australia's Net Zero Plan² expects that as much as $170 \text{ MtCO}_2\text{-e yr}^{-1}$ (some 30% of current emissions) might still exist by 2050 and need to be offset in this way.

Given this reliance on carbon removal, we need confidence in our understanding of how the processes driving the uptake and release of carbon (i.e. the land and ocean carbon cycle) will respond in the future, including how they will respond to changes in the climate itself. Nature-based carbon removal solutions that ignore the role of a changing climate could create future risk for Australia's emissions reduction efforts.

Climate Systems Hub researchers are working to address this knowledge gap, with research focusing on the quantification of Australia's current carbon budget³, simulating Australia's natural carbon cycle into the future^{4,5}, and completing assessments of the climate and carbon-cycle impacts of possible afforestation activity⁶.





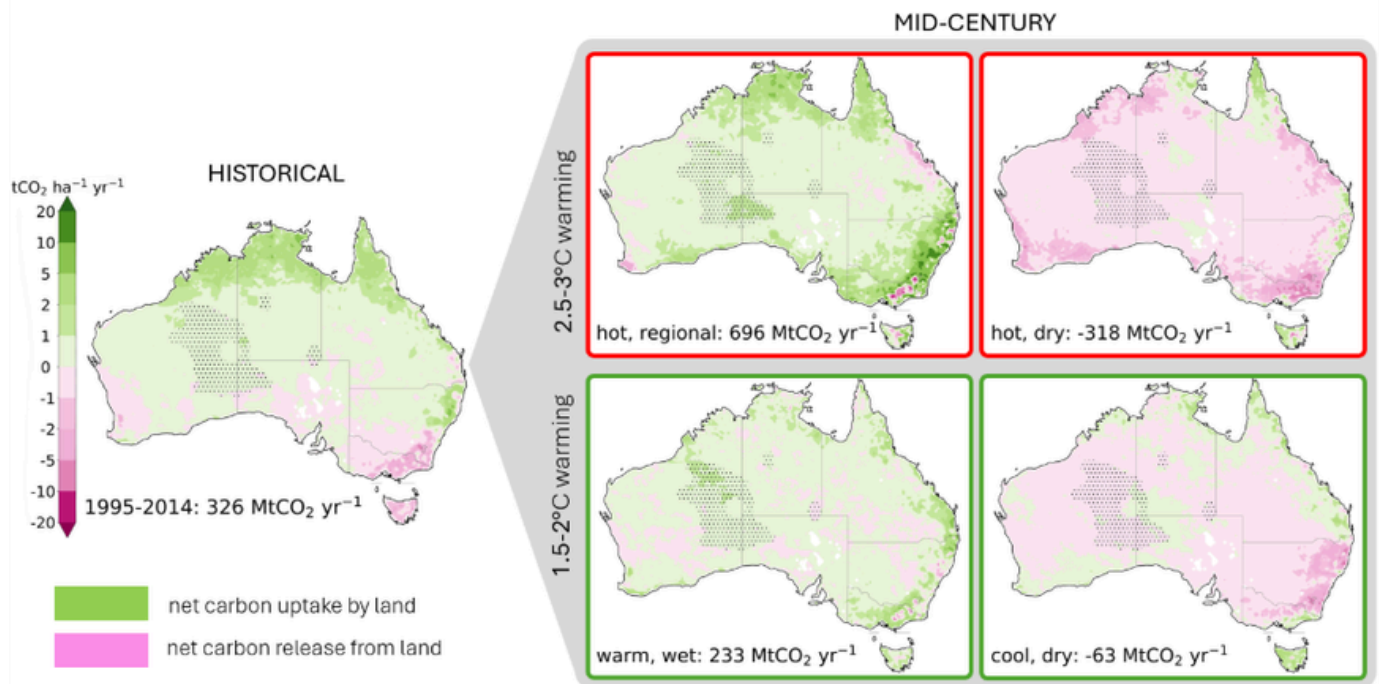
The land carbon-cycle: CO₂ exchanges between land carbon stores and the atmosphere (generated by gemini.ai)

Australia's present-day carbon budget

Climate Systems Hub research found that, over the period 2010–2019, Australia's land carbon cycle acted to offset approximately half of our CO₂ (one third of our CO₂-e) emissions from fossil fuel consumption^{3,7} – though this is highly variable from year to year.

Two processes dominate the continent's land carbon budget – carbon uptake via photosynthesis and carbon release via respiration – alongside many smaller processes (e.g. from land-use, weathering and the net effect of bushfires and other disturbances). Photosynthesis by plants combines energy from the sun, water and CO₂ into sugars by which plants grow, locking carbon into the land. Respiration, by plants, animals and organisms in soil, extracts energy from sugars and other organic matter to power cellular activity, releasing CO₂ to the atmosphere as a by-product. Continentally, photosynthesis and respiration rates are each approximately 20 times the nation's emissions from combustion of fossil fuels^{3,4} yet they nearly cancel each other out in the long-term net exchange. The large year-to-year variability and differences across ecosystems often make it difficult to estimate the long-term net carbon balance.

Net carbon dioxide uptake is stored on the land as organic matter in soil, litter and plant biomass. While remote sensing methods, including from satellites and aircraft, can estimate changes in above ground biomass, monitoring for change in the below ground carbon is much harder. Future change in Australia's land carbon sinks could involve change in all processes in the carbon cycle, and to biomass, litter and soil carbon. To fully understand present-day conditions and predict future changes requires a modelling approach to translate weather, climate and ecosystem productivity into estimates of carbon uptake/release and total carbon stored¹.



Projections of the natural land carbon uptake rate (as measured by net ecosystem production) at mid-21st century (2040–2059) under a selection of future climates⁴. A positive value indicates uptake of carbon by the land. Projections with a green box (bottom) are consistent with the Paris Agreement targets (2 °C global warming with overshoot, SSP1-2.6), those in a red box (top) are consistent with a 4 °C global warming at end of century (SSP3-7.0). The ‘hot, regional’ case is characterised by regionally varying impacts on rainfall.

Australia’s land carbon cycle is very sensitive to changes in climate

Australia’s land carbon sink, led by the uptake of CO₂ by vegetation, is very sensitive to changes in climate. Our modelling and analysis^{4,5} indicate that:

- Changes in rainfall patterns are key to Australia’s carbon future since access to water is necessary for both photosynthesis and respiration to occur. The net effect of changes in rainfall varies strongly by location. Continentally, every 100mm yr⁻¹ increase in rainfall leads to approximately 360 MtCO₂ yr⁻¹ more in net sequestration. Conversely, we expect reduced carbon sequestration if rainfall declines in a future climate. Rainfall will remain the dominant driver determining year-to-year variability.
- Increasing temperature leads to increasing demand for water and increasing microbial activity. This leads to both decreases in CO₂ uptake as plants act to minimise water loss if water is scarce, and increased rates of respiration. Every 1 °C increase leads to approximately 220 MtCO₂ yr⁻¹ less in net carbon sequestration.
- Increasing atmospheric CO₂ concentrations, due to the combustion of fossil fuels and land clearing, result in increased efficiency in the rate of CO₂ uptake by vegetation (the CO₂ fertilisation effect). A 100 ppm increase in CO₂ leads to approximately 160 MtCO₂ yr⁻¹ more net carbon sequestration; however, the effect diminishes with time and with further increases in CO₂ concentrations.
- Photosynthesis requires access to nutrients including nitrogen and phosphorus. Australia’s nutrient limited soils act to inhibit increases in CO₂ uptake below what would be expected given changes in climate^{5,6}.

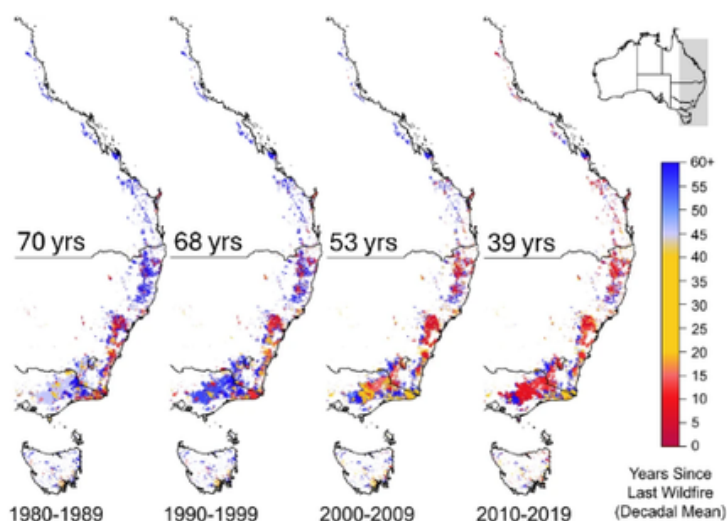
Future climate projections for Australia range from a warmer to a hotter climate, and from a wetter to a much drier climate, with large regional differences. Most of the climate futures assessed indicate Australia will remain a land carbon sink. However, the range in possible future climate leads to a large uncertainty – between -320 to $+800$ $\text{MtCO}_2 \text{ yr}^{-1}$ by mid-century^{4,5,6} (corresponding to -2 times to $+2.7$ times the 2010–2019 natural net land carbon sink³). Regional change in the land carbon sinks is also uncertain, depending on the level of local climate change realised.

Change in disturbance regimes

Disturbances, particularly fire, play an important role in determining the net carbon uptake and the total carbon stored in vegetation and soils. Changes to the disturbance regimes, whether linked to climate or direct human influences or not, will also play an important role in determining the future of Australia's land carbon sinks.

The total area burnt by bushfires has been increasing across the continent over the past three decades. The fire return interval in the forests of the southeast of the country, the most carbon-dense ecosystems in Australia, has become shorter from an average of fire occurring every 68 years during the decade of the 1990's to 39 years in the decade of the 2010's⁸.

Nationally, gross fire emissions are of the same magnitude as Australia's fossil fuel emissions, but fire emissions are compensated for by increased carbon uptake during post-fire regrowth in the years following³. Net emissions associated with fires (burning minus regrowth) in the future will depend on changes in fire weather due to climate change, changes in fire regimes (vegetation type and fuel amount), the capacity for ecosystems to recover, and human management. This connects and compounds the uncertainties from climate with those from ecology and societal response and adaptation.



Observed bushfire return period for south-eastern Australia forests over the satellite period (figure adapted from Canadell et al. 2021⁸, Nature Communications) and (right) impact of the 2025 Hall's Gap, Victoria bushfire (A. Bennett)

Looking ahead

The wide range of the projected response of the natural land carbon sinks to climate change and linked changes in disturbance represents a challenge for policy. Our analysis suggests that the response of the land carbon sinks to future climate change could support or substantively hinder progress toward net-zero, underscoring the importance of continued research.

This wide range is mostly due to the differences in rainfall projections under different emission scenarios and associated modelling uncertainties. This analysis seeks to explore Australia's carbon cycle under future climate, focussing on regional to continental scales and the multi-year response. Most proposed mitigation actions are, however, inherently local. Assessments for these smaller scales typically require increased tailoring to the specific ecosystems involved, additional information regarding e.g. history of land use to be utilised, and dedicated validation.

Further targeted research is needed:

1. to improve the representation of Australia's varied landscapes and unique ecosystems within these assessments, involving both calibration and incorporation of additional processes, and
2. to constrain our climate change projections (which future is more likely?),
3. to explore regional differences to determine where revegetation would be most effective and resilient to future climate change, and
4. to incorporate the impacts of proposed revegetation activities, bushfires and other disturbance into our estimates for Australia's future carbon budget.



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