Australia's land use future

Inputs and assumptions

TECHNICAL REPORT | MAY 2026

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ABOUT US

Climateworks Centre bridges the gap between research and climate action, operating as an independent not-for-profit within Monash University. Climateworks accelerates ambitious, evidence-based action for net zero in Australia and Southeast Asia.

A partnership between Climateworks Centre and Deakin University, the Land Use Futures program identifies and supports pathways for sustainable land use in Australia, balancing primary production, biodiversity conservation, climate mitigation and other societal goals.

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Document overview

This report provides the evidence base underpinning the modelling in the accompanying report, Australia’s land use future: A thriving economy and environment through an integrated approach. It is designed to demonstrate how Climateworks Centre and Deakin University have operationalised national-level climate, biodiversity and agricultural objectives to explore diverse, Paris-aligned and nature-positive land use pathways.

Recognising that managing Australia's land transition requires substantial coordination and touches both public and private industries, as well as civil society, this document is structured to serve two distinct purposes:

- **Mapping physical interventions**: It outlines the land use solutions and technologies available within the model to manage Australian landscapes, balancing simultaneous environmental, energy and agricultural demands.
- **Detailing model mechanics**: It summarises the specific constraints, data inputs and economic assumptions used to define the boundaries of the modelling.

The appendices provide further information about input data layers, how the Land Use Trade-Offs model version 2 (LUTO2) is soft-linked with the AusTIMES model, and additional model functionality that was not used in the presented scenarios.

Introduction

Incorporating nature into Climateworks Centre's decarbonisation modelling

Climateworks Centre's 2023 whole-of-economy decarbonisation scenarios provide an evidence base for how Australia can reduce its emissions in line with the Paris Agreement goals (Climateworks Centre 2023a). The modelled pathways in this document and underpinning the *Australia's land use future* report represent an evolution of Climateworks' 2023 scenarios to explore what a nature-positive, Paris-aligned transition means for Australia's landscapes. Many modelling exercises focus on climate or biodiversity outcomes in isolation, an approach that is misaligned with growing evidence that climate change and nature loss are interlinked (IPBES and IPCC 2021; WWF 2024; IPBES 2024). This project aims to bridge the gap by providing clear, data-driven scenarios that map where and how these goals align.

Why land planning and management are crucial for the transition

Reimagining how Australia manages its landmass presents a profound opportunity to simultaneously secure economic prosperity, agricultural resilience and environmental health. Australia's federal decarbonisation plans require rapid reductions in emissions alongside significant biological carbon sequestration (DCCEEW 2025; Treasury 2025). Alongside the growing demand for carbon sequestration driven by climate policies, Australia has committed to restoring and conserving nature in alignment with the Kunming-Montreal Global Biodiversity Framework (GBF) goals (DCCEEW 2024, 2026). Delivering all of these outcomes will involve the strategic deployment of renewable energy infrastructure, biological carbon sequestration and widespread ecosystem restoration.

Rather than viewing these land uses as competing with growing agricultural demand, a coordinated approach can support landscapes to achieve these goals concurrently. Healthy ecosystems and restored biodiversity are not just vital carbon sinks; they provide the non-substitutable ecosystem services that actively underpin a resilient agricultural sector and broader society (WWF 2024; Institute and Faculty of Actuaries 2025; DEFRA 2026). Navigating the forthcoming shifts in land use requires sophisticated, systems-level planning. By strategically managing this transition, Australia can turn the complex puzzle of intersecting land demands into a generational opportunity for sustainable growth.

What is LUTO2, and how can it help with integrated scenario planning?

Australia's land use future report draws on the Land Use Trade-Offs model version 2 (LUTO2) to generate spatiotemporal insights (i.e. mapped spatially and considering changes over time) into the land use implications of complex interactions between climate, nature and agricultural production goals. The model identifies the most cost-effective spatial distributions of future potential land use transitions to simultaneously meet agricultural demand and climate and environmental objectives under different climate, demand and policy futures. This internal model decision-making is referred to as the 'endogenous' functionalities of the model. LUTO2 also incorporates 'exogenous' input data and assumptions that a model user defines to set certain objectives and constraints.

Developed through a collaboration between Deakin University and Climateworks, the model is a cornerstone of Climateworks' Land Use Futures program, which aims to inform Australia's transition to sustainable food and land systems. A description of LUTO2 is provided below the overview of the scenario and sensitivity analyses.

Scenario design and assumptions

The core scenario and sensitivity analyses used in the *Australia's land use future* report are outlined below. Further information about how key elements of these are operationalised is provided under the following sections on LUTO2's sustainability solutions and indicators.

Core scenario

The core scenario broadly reflects Australia's current climate and nature restoration commitments while still meeting anticipated increases in agricultural demand. The core scenario internalises Australia's Nationally Determined Contribution (NDC) commitments and, more broadly, its commitments to the Paris Agreement.[1] It implements a moderate interpretation of Australia's nature restoration targets and uses business-as-usual (BAU) projections for domestic agricultural demand and for exports.

The core scenario reflects a world where Australian climate and nature ambition meets current environmental commitments, while also meeting projected agricultural demand, underpinned by immediate strengthening of policy and technological ambition. We contextualise these changes within BAU socioeconomic trends and expected temperature increases (the IPCC's 'middle of the road' Shared Socio-Economic Pathway [SSP] 2). The applied climate change trajectory (Representative Concentration Pathway [RCP] 4.5 – an 'intermediate' trajectory likely to result in 2–3 degrees Celsius of warming by 2100) reflects Australia's limited capacity to unilaterally direct global greenhouse gas emissions trajectories.

TABLE 1: OVERVIEW OF KEY TARGETS AND ASSUMPTIONS APPLIED TO THE CORE SCENARIO

SCENARIO	WHOLE-OF-ECONOMY CARBON BUDGET AND LIKELIHOOD (2025–2050)[2]	GLOBAL AND DOMESTIC SSP RCP	BIODIVERSITY RESTORATION TARGET	AGRICULTURAL DEMAND
Core scenario (Current targets)	1.8ºC (67%)	SSP2-RCP4.5	30% of 'priority' degraded areas restored by 2030, increased to 50% by 2050[3]	Increases based on BAU trends

Sensitivities

Climateworks and Deakin University modelled a series of sensitivity analyses, each changing a specific variable or constraint (see below). These sensitivities present a counterfactual to the optimised cost-effective pathway identified by the core scenario, which is designed to align with

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[1] The core scenario's decarbonisation objectives are broadly reflective of the 'baseline' scenario in the Australian Government's sectoral pathways modelling (DCCEEW 2025; Treasury 2025) and the Climate Change Authority's 'Global 2°C (G2)' scenario (CSIRO 2025).

[2] The carbon budget is calculated using updated global emissions budgets derived from IPCC estimates. These global estimates are downscaled into an Australian budget following the method established by Meinshausen and Nicholls (2023). We use DCCEEW national carbon emissions estimates up until the end of 2024 to constrain AusTIMES starting from 1 January 2025, reflecting the modelling start year of 2025.

[3] See section below on biodiversity targets.

current targets. By analysing the differences between the core scenario and its sensitivities, we explore how an integrated planning approach could respond to uncertain futures and to different priorities.

Exploring the synergies between high nature and climate ambition:

The ‘higher biodiversity restoration’ sensitivity centres around more transformational restoration targets over a larger assumed area of ‘priority’ degraded lands for 2030 and 2050, while also linking to a tighter carbon budget. It shows the synergy between biodiversity and sequestration outcomes.

Prioritising regional equity in land transitions:

The ‘regional constraints’ sensitivity prioritises the equitable distribution of land use changes between regions, to avoid spatially concentrating opportunities and disruptions from transition. It does this by capping the extent of land use transitions between agricultural and non-agricultural land uses in each region.

TABLE 2: OVERVIEW OF THE SCENARIO AND SENSITIVITIES

SENSITIVITY	DESCRIPTION	PURPOSE	LEVERS
Core scenario		Foundational scenario that outlines an optimal path to achieving Australia’s climate, nature and agricultural priorities within an orderly, coordinated and integrated transition.	
‘Higher biodiversity restoration’	Incorporate higher ambition biodiversity restoration targets	To explore the implications of prioritising more widespread restoration, which also represents higher sequestration levels and an accelerated decarbonisation pathway.	Increase the biodiversity priority score threshold to 25% (from 15% in the core scenario), and therefore the total area restored in target years.
‘Regional constraints’	Constrains conversion of agricultural land to non-agricultural land uses, applied at a regional level	To explore a more equitable distribution of the ecosystem service benefits and social implications of change on communities. Also demonstrates the economic trade-offs between distributed change versus an unconstrained scenario that maximises application of comparative advantages between different geographical areas.	Constraining the amount of change to each non-agricultural land use to less than 5% of the LUTO2 study area in each Natural Resource Management (NRM) region.

Overview of the LUTO2 model

LUTO2 is an open-source[4], integrated environmental-economic land systems model that serves as a national foresighting capability and policy tool. It explores the economically optimal spatial distribution of land use and land management activities between 2010 and 2100 to achieve targets.

Solve boundary and data layers

LUTO2's foundational datasets cover the entire Australian landmass (over 7 million km²) and are used to inform the application of sustainability solutions[5], which are applied to grid cells defined as privately owned agricultural and crown lease land[6] (over 4 million km^2) at a spatial resolution of 1.1 km².

LUTO2 integrates a comprehensive range of baseline spatiotemporal data layers, including historical land use, soil profiles, water yield and biodiversity metrics. Agricultural productivity, economic costs and environmental data are quantified for each individual grid cell.

Furthermore, the model actively accounts for future uncertainties by integrating data on the projected impacts of climate change across land, water, agriculture and ecosystems under various SSP and RCPs.

Objective function

LUTO2's objective function can be set to either maximise the aggregate profit of the whole system or to minimise the transition costs required to meet scenario constraints across the model's grid cells.

The 'maximum profit' approach directs the model to select land use configurations that yield the highest net financial return from both agricultural production and any carbon or biodiversity revenue, while meeting prescribed targets. Conversely, the 'least system cost' option minimises the total cost of meeting agricultural demand and emissions constraints, prioritising economic efficiency. In both modes, LUTO2 evaluates the potential net financial return of every viable activity for each grid cell and then determines the optimal system-wide configuration. This ensures that the model balances competing climate, biodiversity and agricultural production objectives while strictly satisfying all defined environmental limits, including water use constraints to avoid water stress.

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[4] LUTO2's code base and full documentation is freely available on GitHub at https://github.com/land-use-trade-offs/luto-2.0 (Bryan et al. n.d.)

[5] Refer to the 'LUTO2 sustainability solutions' section for more information.

[6] The study area represents approximately 60 per cent of Australia's landmass. LUTO2 cannot apply solutions (changes in land use or management) to areas outside the study area, however, parameters such as water use and biodiversity from public and Indigenous lands are considered when calculating targets and optimising land use within the study area. See Caveats and limitations section.

LUTO2 sustainability solutions

Changes in land use and land management are both applied by LUTO2 as it optimises for environmental and economic objectives. This section defines agricultural land uses, non-agricultural land uses and land management options that were used in the scenarios for the *Australia's land use future* report.

Land use options

Agricultural land use

LUTO2 models the production of 28 categories of agricultural commodities subject to exogenous demand constraints.[7] While in practice, landowners operate rotational production, LUTO2 assumes a single predominant land use for a given area, drawing on a baseline dataset from the 2010 Land Use of Australia map, see Figure 1 (ABARES 2016a). We model agricultural commodities across five main land use categories (Table 3).

TABLE 3: OVERVIEW OF AGRICULTURAL LAND USES IN LUTO2

LAND USE CATEGORY	DESCRIPTION	LAND USES
Horticulture	Specialised, intensive cultivation of perishable, high-value plants, including fruits, nuts, seeds, herbs and flowers.	'Apples', 'Citrus', 'Grapes', 'Nuts', 'Pears', 'Plantation fruit', 'Stone fruit', 'Tropical stone fruit'
Cropping	Broadacre cultivation of crops primarily for grain, seed, or animal feed, typically operating on large scales across distinct summer and winter growing seasons.	'Hay', 'Summer cereals', 'Summer legumes', 'Summer oilseeds', 'Winter cereals', 'Winter legumes', 'Winter oilseeds'
Intensive cropping	Cultivation of high-yielding, resource-intensive non-cereal crops and vegetables, frequently relying on irrigation and targeted nutrient management.	'Cotton', 'Other non-cereal crops', 'Rice', 'Sugar', 'Vegetables'
Livestock	Grazing of ruminants optimised for meat, wool and dairy production. This occurs on either modified (cleared and pasture-sown) or natural (intact native vegetation) lands.	'Beef - modified/natural land', 'Sheep - modified/natural land', 'Dairy - modified/ natural land'
Unallocated lands	Lands within the model's 1.1 km² geographic boundary that are not assigned to active agricultural production within the baseline land use map.[8]	'Unallocated - modified land' 'Unallocated - natural land'

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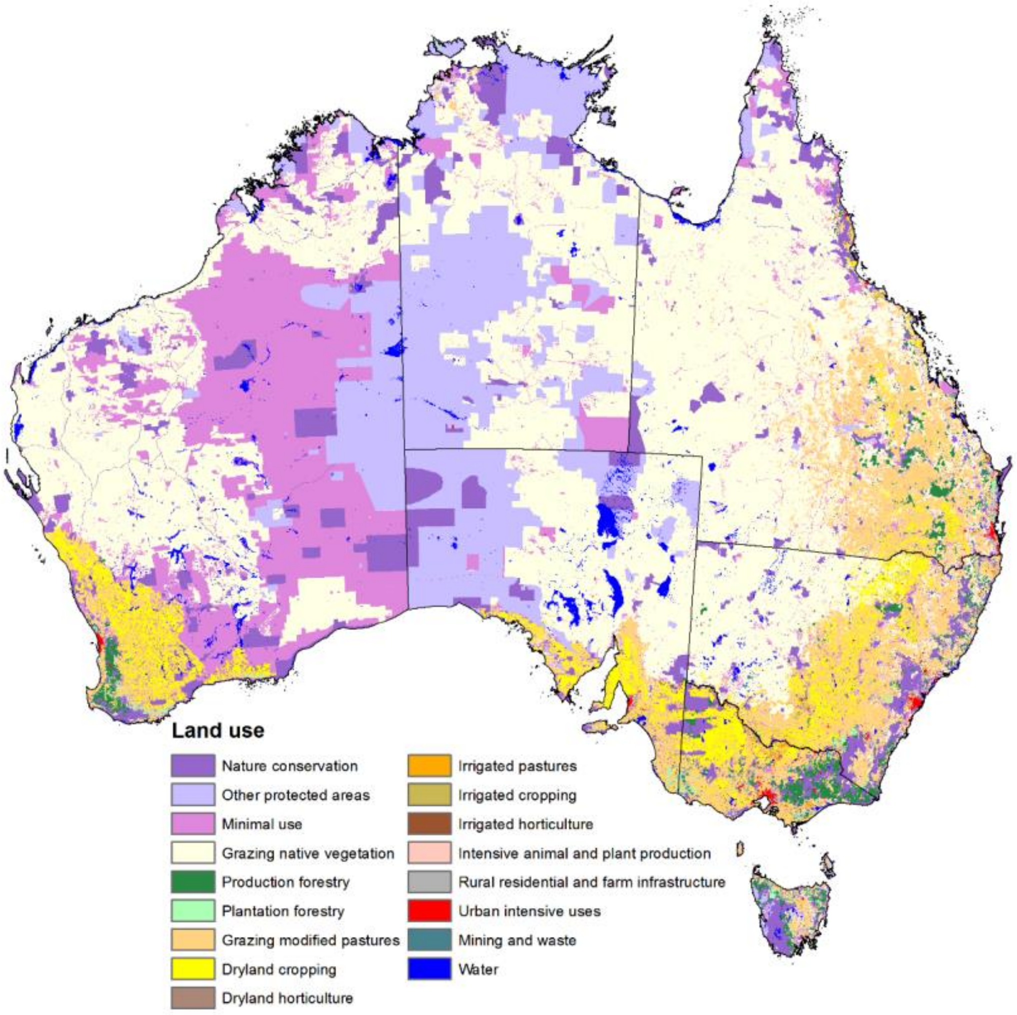
[7] See the 'Agricultural demand and production' section for more information on functionality and specific scenario settings chosen for this modelling.

[8] ABARES' 2010-11 Land Use Map (ABARES 2016a) uses the Australian Land Use and Management (ALUM) classification system to categorise different land uses (ABARES 2016b), which are also adopted for LUTO2.

FIGURE 1: LAND USE OF AUSTRALIA 2010–2011 VERSION 5, OBTAINED FROM ABARES (2016A)



LUTO2 does not explicitly include pork, poultry, aquaculture or alternative protein sources as available land uses for any of the grid cells, as their direct land footprint tends to be small compared to the 1.1km^2 grid resolution. Their production emissions are modelled and their indirect land and water use requirements for feed are calculated through LUTO2's demand model before being allocated spatially within LUTO2.

LUTO2's agricultural production takes place on modified (cleared) or natural lands. Agricultural lands are also classified as dry or irrigated, which affects productivity and production costs.

Non-agricultural land use

LUTO2 can choose to switch from agricultural to non-agricultural land uses to improve simulated environmental outcomes such as increased carbon sequestration rates, avoided emissions and biodiversity compatibility. The majority of these solutions are modelled representations of the Australian Carbon Credit Unit (ACCU) scheme methods, allowing users to test the environmental and economic implications of different ACCU demand scenarios.

The biodiversity contribution scores represent the suitability of each cell for supporting biodiversity, ranging from zero to one. A score of zero represents land unable to support biodiversity, while a score of one represents undisrupted natural land with maximum biodiversity value (see the Biodiversity section below for more information).

TABLE 4: OVERVIEW OF NON-AGRICULTURAL LAND USE METHODS AVAILABLE IN LUTO2

METHOD NAME	METHOD DESCRIPTION	BIODIVERSITY CONTRIBUTION SCORE USED IN SCENARIOS
Environmental plantings	Revegetation of land that has been cleared for at least five years with trees, shrubs and/or grasses that are native to the local area. Environmental plantings are assumed to be more expensive than carbon forestry but are of greater environmental benefit. The carbon stock held in the land use's biomass is derived using FullCAM estimates across Australia for mixed species.	0.7
Riparian restoration	Restoration of riparian (vegetation corridors along streams and rivers) areas. Healthy riparian ecosystems offer carbon storage potential alongside environmental benefits such as improved water quality, reduced soil erosion and increased habitat availability, which can extend beyond the area restored (for this reason, a biodiversity contribution score of more than 1 has been applied to this method).	1
Carbon forestry	Afforestation (new tree plantings) on cleared agricultural lands for the purposes of medium-term to long-term sequestration of carbon dioxide. This option is assumed to be more cost-efficient for the purposes of sequestering carbon, although this use of monocultures provides minimal habitat for native species and can negatively impact local water catchments by altering natural runoff patterns. The carbon stock held in the land's biomass is calculated using the FullCAM tool for the *Eucalyptus globulus* species or Mallee plantings.	0.12
Agroforestry	Reforestation of vegetation, such as trees or shrubs, on agricultural paddocks. In LUTO2, these are modelled as belt plantings. In addition to biodiversity benefits, these can also provide protective and other benefits for agricultural production; however, the latter are not quantified at this stage in LUTO2.	0.7 (applied to the proportion of the cell reforested)
Farm forestry	Carbon forestry (afforestation of single species chosen for their rate of carbon accumulation) on agricultural paddocks, in combination with sheep or beef grazing.	0.12
Other restoration/ conservation	Allowing natural ecosystems to recover by fully removing livestock and undertaking ongoing management (e.g. invasive species control) in areas such as native grasslands. This method has negligible uptake in the scenarios.	0.75

Mixed land use

LUTO2 allows for mixed agricultural and non-agricultural practices to reflect production flexibilities available to real-world landholders. Specifically, LUTO2 includes three major forms of mixed land uses:

- **Non-agricultural land uses:** Agroforestry and farm forestry, which combine plantings with an agricultural land use.
- **Land use mosaic:** Uptake of multiple land uses in the same grid cell (most commonly this occurs with riparian plantings mixed with agricultural production).
- **Agricultural management solutions:** Managed regeneration (reduced stocking rates of livestock to encourage native vegetation growth) and renewable energy generation assets (onshore wind and utility solar).[9]

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[9] Renewable energy generation assets are a recent addition to the LUTO2 model and have not been included in the scenarios for the report, Australia's land use future. They will be the subject of upcoming analysis from Climateworks. A description of this module is included in Appendix 2.

Agricultural land management activities

Beyond switching land uses entirely, LUTO2 can apply specific bundles of management practices and technologies to existing agricultural land. These solutions are designed to simultaneously increase yields, reduce emissions, increase water retention and/or enhance biodiversity. To reflect logistical realities, the model enforces a technical adoption ceiling each year, representing the maximum portion of a given commodity’s land use that can feasibly 'purchase' a management bundle.

TABLE 5: OVERVIEW OF LAND MANAGEMENT SOLUTIONS AVAILABLE IN LUTO2

LAND MANAGEMENT BUNDLE	BUNDLE DESCRIPTION	RELEVANT COMMODITIES	SUSTAINABILITY INDICATOR IMPACTS
Methane reduction bundle Plant and synthetic feed additives (*Asparagopsis taxiformis* and 3-Nitrooxypropanol), manure management (including biogas generation)	Additives to livestock feeds and covered anaerobic lagoons featuring electricity generation from biogas with the intention of reducing methane emissions from livestock production. *A. taxiformis* is a seaweed feed additive, and 3-Nitrooxypropanol is a synthetic enzyme feed additive for methane reduction.	Dairy, sheep, cattle, pigs and poultry	Methane emissions, annual costs per head (animal)
AgTech (non-energy emissions intensity) bundle Enhanced efficiency fertilisers (slow and controlled-release fertilisers) and nitrification inhibitors	Enhanced-efficiency fertilisation technologies that improve soil conditions and prevent denitrification of soils for cropping and horticultural farming.	Intensive cropping, cropping, horticulture	Nitrogen use efficiency, nitrous oxide emissions, water use, productivity (yield), annual costs per hectare
AgTech (energy emissions intensity) bundle Variable rate irrigation and planting systems, digital agriculture (farm monitoring and tracking, Internet of Things)	Digital optimisation of farming practices using monitoring and tracking sensors, variable rate systems and smart systems to reduce waste in farming.	Intensive cropping, cropping, horticulture	Nitrogen use efficiency, nitrous oxide emissions, carbon dioxide emissions, water use, productivity (yield), annual costs per hectare
Biochar	Product produced via thermal transformation of organic matter in an oxygen-limited environment.[10] Application to soils provides agronomic benefits and long-term carbon sequestration opportunities, although only the former has been modelled here to avoid double-counting of carbon from the input feedstocks to the biochar.	Intensive cropping, cropping, horticulture	Carbon dioxide storage, carbon dioxide emissions, nitrous oxide emissions, nitrogen use efficiency, water retention, productivity (yield)
Savanna fire management	Planned burning of northern Australian savannas in the early dry season to prevent the spread of unplanned fire	Cattle, Unallocated natural land	Carbon dioxide storage, carbon dioxide emissions, risk management (productivity

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[10] Definition sourced from research review by Joseph et al. 2021.

	in the late dry season. These methods result in fewer greenhouse gas emissions and more carbon being sequestered in dead organic matter, as well as reducing risks to infrastructure and fodder.		and costs), biosecurity and biodiversity
Managed regeneration e.g. Human Induced Regeneration (HIR)	Regeneration of native forest where regrowth has been suppressed for at least 10 years. This includes reducing livestock grazing by 50%, protecting against feral animals, managing non-native plants or preventing native regrowth suppression. This is an expected component of the forthcoming Integrated Farm and Land Management ACCU method.	Cattle, sheep	Carbon dioxide storage, soil health and biodiversity.

Renewable energy

Renewable energy generation has recently been integrated into LUTO2 to model trade-offs and co-benefits with agricultural and other land uses. Renewable energy modelling was not used in the scenarios for the *Australia's land use future* report, as it is still being tested, but is outlined in Appendix 2.

LUTO2 components

Biodiversity

To meet biodiversity targets, LUTO2 transforms existing land uses by switching to non-agricultural land uses[11] or applying certain agricultural management solutions to increase their ecological value. Biodiversity contribution scores and biodiversity priority scores, which quantify the importance of different land uses for biodiversity conservation and restoration, are key components of how the model operationalises GBF 2030 targets (Convention on Biological Diversity n.d.a).

TABLE 6: QUANTIFYING BIODIVERSITY VALUE AND RESTORATION IMPORTANCE IN LUTO2

SCORE	DESCRIPTION	SPATIAL DATASET(S)	UNIT (0–1)	PURPOSE
Biodiversity contribution	Quantifies how much each grid cell contributes to supporting biodiversity, based on median expected habitat conditions for land use types and land management solutions.	Habitat Condition Assessment System (HCAS 3.1)	0 (unable to support biodiversity), 1 ('Unallocated - natural land')	Quantifies the 'effective area' of restoration under different land use change simulations (area-based GBF targets)
Biodiversity priority	Quantifies the relative benefit each grid cell has to conservation and restoration, based on species habitat suitability modelling	Climate refugia species modelling (Archibald et al. 2024), incorporating habitat connectivity scores[12]	1 (highest biodiversity priority, based on current and future habitat suitability)	Informs where the most biodiversity gain can be achieved from effective restoration (identifies priority areas)

LUTO2 operationalises international conservation goals by converting broad policy targets into spatially explicit mathematical constraints. Rather than treating all land as equal, the model employs a quality-weighted area method to reflect the contributions that agricultural land uses make to aggregate biodiversity levels. This method prioritises high-value conservation outcomes by integrating the quantity of relevant land with the quality of its biodiversity contribution.

Core scenario settings

The central biodiversity constraints in this analysis are targets to improve aggregate biodiversity quality levels in high-priority areas for future habitat suitability under climate change. Since LUTO2's primary lever for improving biodiversity is restoration of degraded lands, the modelled targets are

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[11] See 'Table 4: Overview of non-agricultural land use methods available in LUTO2'Biodiversity habitat quality for non-agricultural land uses.

[12] LUTO2 includes a parameter that can reduce raw biodiversity priority scores based on a habitat connectivity score (thus reducing the priority level of poorly connected areas). Habitat connectivity scores can be derived from a landscape connectivity layer calculated from the Distance-Weighted Index (calculated from distances between natural lands in the Land Use of Australia map) or National Connectivity Index (NCI 2.0) data.

indicative of GBF Target 2: Restore 30 per cent of all Degraded Ecosystems (Convention on Biological Diversity n.d.b). The model primarily deploys high-yielding restoration activities, such as:

- Environmental plantings (native species reforestation)
- Riparian restoration (vegetation corridors along waterways)
- Agroforestry (integrated mixed-species trees and grazing)
- Managed regeneration (including Human-Induced Regeneration on agricultural land)

Three important distinctions should be noted in how the restoration target has been operationalised:

1. The restoration target in Australia's Strategy for Nature 2024–2030 (DCCEEW 2024) refers to priority degraded areas being under effective restoration by 2030. The Australian Government has not yet defined the boundaries of these priority degraded areas. In these scenarios, land in LUTO2's study area was ranked by its potential biodiversity value, with the highest-yielding 15 per cent designated as the 'priority' baseline.
2. Under the quality-weighted area method, the aggregate biodiversity quality uplift – from both non-agricultural land uses, such as environmental plantings, and changes in agricultural land uses – is equivalent to restoring 30 per cent of priority degraded lands by 2030.
3. While the Convention on Biological Diversity lacks a quantifiable 2050 target, our scenarios assume a continued trajectory of ambition, increasing the required quality-weighted uplift to 50 per cent of the priority baseline by 2050.

In the quality-weighted area calculations, the biodiversity quality of agricultural land uses is derived by the median expected habitat conditions, from the Habitat Condition Assessment System (HCAS 3.1). For non-agricultural land uses, LUTO2 uses the biodiversity contribution coefficients detailed in Table 4.

Sensitivity

HIGHER BIODIVERSITY RESTORATION

For the higher biodiversity ambition sensitivity, we increased the priority restoration threshold to expand the area of land that is assumed to be 'priority' degraded lands under LUTO2's restoration target. The area is expanded from the highest-biodiversity yielding 15 per cent of land up to 25 per cent. In this sensitivity, we specified that quality-weighted area restoration is equivalent to 30 per cent of the 25 per cent highest-priority degraded lands by 2030, and 50 per cent of the 25 per cent highest-priority degraded lands by 2050.

Additional model capabilities

Climateworks and Deakin University are continuing to explore the implications of the various options for modelling biodiversity targets. While the scenarios for this work use a single restoration target, LUTO2 has the capability to operationalise other aspects of the GBF targets, as described in Appendix 2.

Greenhouse gas emissions

LUTO2 is loosely-coupled, or soft-linked[13], with Climateworks Centre and CSIRO's AusTIMES, which models how the whole of the Australian economy could decarbonise in a way that reflects the lowest overall cost between now and 2050. The scenarios translate Paris Agreement goals into specific emissions limits for each economic sector using fair share carbon budgets.[14]

The soft-linking process involves alignment of several agricultural technology and land-based sequestration assumptions between models to create internally-consistent modelling outputs. Each model operates separately, retaining its individual characteristics, while benefiting from the findings of the other model to build more coordinated and consistent pathways.

Greenhouse gas emissions from agriculture have been specified at the level of individual gases (i.e. CH_4, N_2O, CO_2) from specific components of the farming system, based on lifecycle assessment and gross margin handbooks. Tree growth modelling (FullCAM) is the basis of LUTO2's carbon sequestration calculations for above and below ground biomass. While an exogenously defined carbon price can be incorporated into LUTO2, to incentivise land use changes and management activities aligned with abatement, cumulative emissions targets were instead used for this report.

Core scenario setting

AusTIMES defines the emissions constraints for the agriculture and land sectors based on a least-cost whole-of-economy pathway. LUTO2 represents this as a maximum carbon allowance for the sector's non-energy emissions. Energy-related agricultural emissions are excluded from LUTO2, as they are best resolved within the AusTIMES energy system model. The core scenario climate targets for Australia are consistent with its national commitments to achieving a global temperature limit of 'well-below 2°C'. Climateworks assumes 'well-below 2°C' aligns with IPCC's global carbon budget of 1.8°C (67 per cent probability).[15] This target broadly aligns with Australia's NDC to the Paris Agreement.

TABLE 7: AGRICULTURE AND LAND CARBON ALLOWANCES DEFINED BY AusTIMES, AUSTRALIA'S *LAND USE FUTURE* CORE SCENARIO

SECTOR	PARAMETER DESCRIPTION	CUMULATIVE EMISSIONS ($MtCO_2e$ 2025–2050)
Agriculture	Net non-energy emissions from Australia's agricultural sector, representing all on-farm non-energy emissions sources from all modelled agricultural activities. All three major types of greenhouse gases are individually modelled and transformed into carbon dioxide equivalent (CO2e) values using GWP100.[16]	2129.17
Land	The net carbon dioxide equivalent (CO2e) emissions sourced from Australia's land sector. This includes both exogenous forecasts for	-2545.31

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[13] Refer to the explainer of the soft-linking process between AusTIMES and LUTO2 in the Appendix.

[14] Refer to the Climateworks Centre decarbonisation scenarios 2023: AusTIMES Modelling Assumptions and Methodology Report for more information on the carbon budget calculation (Climateworks Centre 2023b).

[15] Consistent with approach of recent decarbonisation scenario modelling: *Climateworks Centre decarbonisation scenarios 2023: AusTIMES Modelling Assumptions and Methodology Report* (Climateworks Centre 2023b).

[16] We apply the most recently updated AR6 Global Warming Potential, calculated over a 100-year time frame (GWP100) values in our modelling (Greenhouse Gas Protocol 2024), reflecting its standing as the standard, IPCC approved metric for evaluating the impact of greenhouse gases on global warming (Agrecalc 2024).

	Australia's net LULUCF emissions[17] as well as additional endogenous land-based sequestration available to the model at-cost.[18]	

Sensitivity settings

HIGHER BIODIVERSITY RESTORATION

The 'higher biodiversity restoration' sensitivity also allows us to explore the feasibility and trade-offs of a future where Australia's land-use sequesters more emissions. In addition to higher priority thresholds for biodiversity restoration, the decarbonisation pathways for non-agriculture and land sectors were placed under a stricter carbon constraint than in the 1.8°C (67 per cent probability) core scenario.

The paired AusTIMES scenario for this sensitivity was a whole-of-economy emissions pathway consistent with global temperature limits of 1.5°C (50 per cent probability). This AusTIMES 1.5°C scenario used the same maximum potential sequestration constraints as the 1.8°C (67 per cent probability) core scenario, but LUTO2 was allowed to overshoot these constraints. This allows exploration of a future with more widespread restoration, but puts in place a safeguard so that additional land-based sequestration does not substitute for reductions in fossil fuel emissions, as discussed below.

Emissions equivalency

A unit of carbon dioxide sequestered in vegetation and soils is not strictly 'equivalent' to the same unit of carbon dioxide released through the burning of fossil fuels. This is because fossil fuels introduce 'new' carbon into the atmosphere that was previously in stable geological storage, while nature-based processes manage existing carbon in the current biogenic cycle. Nature's sequestration of emissions generally forms part of a more dynamic and shorter-term carbon cycle, and fossil fuel emissions introduce additional carbon into this cycle, risking those emissions remaining in the atmosphere for millennia.

In these scenarios, this lack of equivalency between geologic and biogenic emissions is partially addressed by applying a discount rate to sequestered emissions to account for their reversibility, as discussed in the 'Climate change physical impacts' section below. However, there is considerable uncertainty about future reversals of sequestered emissions, particularly due to climate change impacts.

Even in the face of this uncertainty, nature-based solutions are crucial to meeting the Paris Agreement climate goals. Any additional sequestration implied by these results, relative to other modelling exercises, is best viewed as a further contribution to drawing down historical anthropogenic emissions, rather than a justification for lower future abatement from other sectors (refer to Groom and Venmans 2023, Matthews et al. 2023 and Keith et al. 2022 for more information on this issue).

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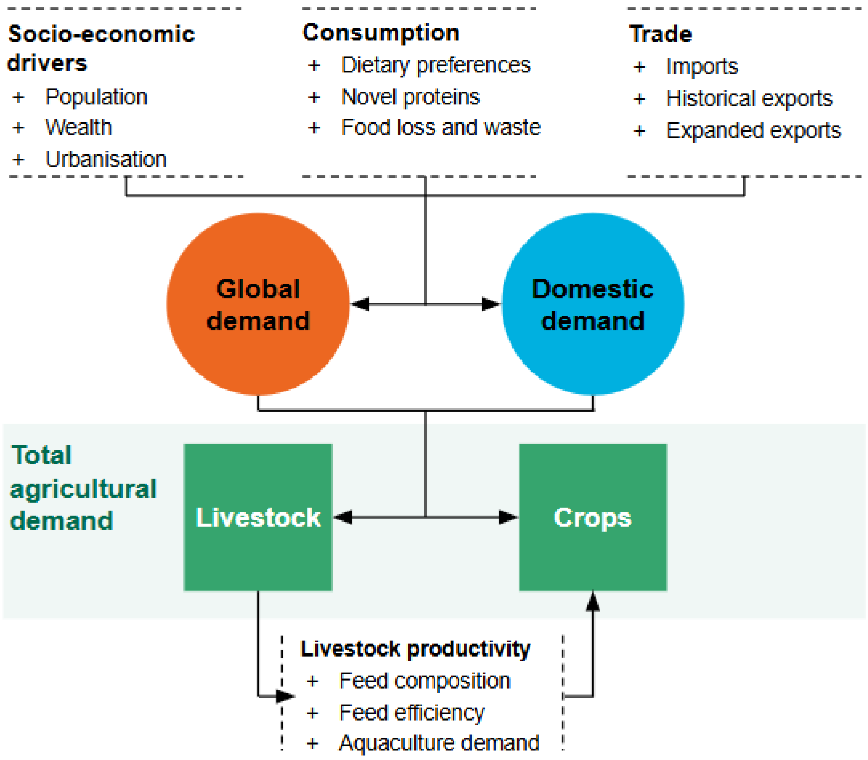
[17] Land Use, Land-Use Change and Forestry UNFCCC forecasts are sourced from Australia's National Greenhouse Gas Accounts (ANGA) using the 'baseline' scenario until 2040. These are extrapolated until 2050 for consistency with the modelling period. We exclude the avoided emissions from these future LULUCF forecasts to ensure emissions only source from future land use changes.

[18] We used the land-based sequestration supply curve generated using LUTO-C to inform the availability and per-tonne costs of land-based sequestration. This same curve is also assumed by CSIRO and Treasury in their recent decarbonisation scenario modelling and largely aligned with ABARES' recent modelled findings (CSIRO 2025; Treasury 2025; ABARES 2025a).

Agricultural demand and production

Australian agricultural production projections used for this report were calculated using a food demand forecasting model developed specifically for LUTO2 (Hadjikakou n.d.). The demand model is fully adapted to the Australian context and estimates the total production expected from Australian agriculture based on key trends domestically and among Australia's main trading partners. These trends relate to population growth, GDP per capita, diet, food loss and waste, feed efficiency, and trade assumptions and Australia's agricultural export orientation. Over 1200 fully user-specified demand scenarios are already available in the LUTO2 model that encompass a range of potential pathways based on combinations of these variables. Figure 2 provides an overview of the food demand model.

FIGURE 2: FOOD DEMAND MODEL FUNCTION OVERVIEW



Activity projections for the agricultural sector derived from LUTO2's exogenous agricultural demand model are implemented into AusTIMES to ensure consistency of production across models.

Core scenario setting

The core scenario and all sensitivities in this report follow a BAU demand pathway (i.e. SSP2 discussed previously). In this pathway, dietary, feed efficiency, waste and loss, and import trends extend from historical trends into the future. The SSP2 pathway is also broadly reflective of AusTIMES production growth assumptions.

Catchment-based water yield

LUTO2 spatially defines water yield under natural conditions for each grid cell, using historical and future rainfall and temperature data from WorldClim and modelled potential evapo-transpiration using the Priestley Taylor index. Projected water yields under different CMIP6 climate change scenarios are determined using a hydrological model (InVEST® Water Yield Model [Natural Capital Alliance 2025]). Water yield within catchment areas outside of the LUTO2 study area is also modelled. Domestic and industrial water use is derived from ABS data and is spatially distributed by catchment, using current and future population as a proxy indicator for water demand.

Water stress thresholds require the water yield for each catchment to be greater than or equal to a percentage of the historical yield under natural conditions. If a catchment is already below this threshold in the base year, then the current water use will be used as the threshold target, and no further extraction is permitted.

Non-agricultural land uses and irrigated agricultural commodities within the same catchment compete for water with domestic and urban users. This means that in water-stressed catchments, switches to more water-intensive land uses can only occur if water becomes available from other land use switches in the catchment. LUTO2 includes a full water trade model where water users can trade water at historical water license prices.

Core scenario setting

Water stress thresholds are set based on the concepts of sustainable yields and planetary boundaries (Climateworks Centre 2022; Steffen et al. 2015). They require the water yield for each catchment to be greater than or equal to 60 per cent of the historical yield under natural conditions.

Climate change physical impacts

LUTO2 incorporates detailed spatio-temporal modelling of climate change impacts across land, agricultural production, water, biodiversity and emissions under four combinations of RCPs and SSPs.

Agriculture: LUTO2 incorporates climate change yield impacts on agricultural outputs modelled using the Global Agro-Ecological Zones model (GAEZ v4) (FAO n.d.).

Carbon sequestration: LUTO2 imposes a 'fire risk' parameter to represent the risk of loss of plantings from bushfires, based on modelling of a 91-year period between 2010 and 2100 inclusive. Generally, the median value from this risk modelling is used, equivalent to an 11 per cent discount, or reduction, applied to carbon sequestration across the lifespan of a carbon project. This discount level is a more conservative estimate than the 5 per cent risk of reversal imputed into the ACCU scheme for 100-year plantings.

Water: LUTO2 integrates modelled climate impacts on catchment-based water yields under Coupled Model Intercomparison Project Phase 6 (CMIP6) climate change scenarios, which feed into the InVEST model of topographic hydrology, including changes in precipitation and evapotranspiration (CMIP n.d.).

Biodiversity: LUTO2 incorporates spatial changes in habitat suitability under climate change for more than 10,600 species of native plants and animals (Archibald et al. 2024; Hu et al. 2026).

Core scenario setting

The scenario and sensitivities model climate impacts using RCP4.5 warming pathways. The climate data used to qualify these impacts comes from the latest CMIP6 (WorldClim n.d), and an ensemble model of eight independent Global Climate Models (GCMs).[19] The applied climate change trajectory (RCP4.5) implies moderate levels of climate physical risks to Australian agricultural yields by 2060. The median 'fire risk' parameter was used, representing an 11 per cent discount on sequestration from plantings.

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[19] BCC-CSM2-MR, CNRM-CM6-1, CNRM-ESM2-1, CanESM5, IPSL-CM6A-LR, MIROC-ES2L, MIROC6, MRI-ESM2-0

Land use switching

LUTO2 simulates dynamic land use flexibility, allowing switching production between agricultural commodities or conversion to or from non-agricultural land uses, in response to market and policy signals. This capability introduces direct competition for land resources, capturing the tension between meeting growing agricultural demand and achieving national environmental targets. Land use switching is constrained by land suitability and incurs upfront transition costs to reflect the economic barriers to land use change. Consequently, the model can identify opportunities for transitioning from traditional agriculture to alternative uses, such as carbon farming or biodiversity conservation, in response to physical climate change impacts and sustainability targets. Land switching between dryland (i.e. rainfed) and irrigated agricultural lands is also possible, subject to water availability and transition costs in relevant areas.

To optimise land use switches that meet all constraints, LUTO2 considers:

- transition costs from one land use type to another over base land use costs (including for switching between irrigated and dryland systems)
- water availability for any dryland and irrigated land switching across time (staying within catchment water yield requirements and water stress threshold)
- change in productivity with spatial shifts in commodity production relative to base land use, across time
- opportunity cost for other land uses.

To optimise the application of agricultural land management solutions, LUTO2 considers:

- additional annual cost of applying the solution over baseline costs
- abatement potential
- productivity increases with applied activity across time
- nitrogen use efficiency with applied solution, across time
- water use efficiency with applied solution, across time.

LUTO2 distinguishes between transition costs, which accrue when a model cell switches land use, and annual costs. A transition cost matrix contains the costs of changing a current land use to another. Upfront capital expenditure for transitioning land use is not amortised to ensure transition costs are fully paid prior to future land-switching. This curbs excessive land-switching behaviour within the model. There are additional costs associated with switching between dryland and irrigated agriculture, reflecting a higher cost of infrastructure investment, including the purchase of permanent water licenses at market price. The geographic feasibility of switching is constrained by local water availability, preventing infeasible land use outcomes.

When calculating the annual costs and benefits of the model's land management solutions, LUTO2 can apply a discount rate to reflect the time value of money over the simulated time horizon. When implemented, this is generally set as a 7 per cent discount rate, consistent with state (DTF 2013) and federal government cost-benefit analyses, including recommendations by the Office of Impact Analysis (OIA 2023).

Core scenario setting

In the core scenario, we do not impose limits on the amount of land use switching that can occur in a given year. The objective of this scenario is to analyse the spatial reallocation of land use in Australia to meet the various environmental and economic targets for the land and agricultural sectors. We impose transition costs to reflect real-world friction and upfront costs associated with changing between different combinations of agricultural land uses.

In the *Australia's land use future* scenarios, upfront capital expenditures were not amortised, mimicking empirical financial and risk barriers to long-term land-use change experienced by landowners. The transition costs, therefore, reflect the full upfront year-on-year costs incurred at the point of modelled land use change.

Sensitivity

REGIONAL CONSTRAINTS (CAPPING AGRICULTURAL TO NON-AGRICULTURAL LAND USE CONVERSION AT THE REGIONAL LEVEL)

The regional constraints sensitivity prioritises the equitable distribution of land use changes at the regional level, to avoid spatially concentrating opportunities and challenges. This is done by constraining change within each Natural Resource Management (NRM) region. The cumulative area of each new non-agricultural land use in each region cannot exceed 5 per cent of the region's total LUTO2 study area.

Caveats and limitations

Intended purpose: The scenarios presented in this report function as normative, target-seeking pathways rather than forecasts of current trajectories, 'BAU' behaviours, or expected market trends. They are not intended as an exhaustive set of all possible pathways but as a small number of optimised, plausible futures. The model's outputs should be regarded as a strategic exploration of what can be achieved under a specific, goal-oriented framework, rather than a deterministic prediction of what will occur.

Linear carbon sequestration: In LUTO2, biological carbon sequestration from permanent plantings is annualised as a constant, linear rate by dividing the total expected lifetime sequestration by an assumed 60-year lifespan. Since tree species across different Australian bioregions typically rapidly accrue aboveground biomass in their first 15–20 years before growth plateaus, LUTO2 underestimates sequestration yields in the early decades of a planting's lifecycle, but overestimates in the later decades of the 60-year horizon.

This conservative approach to modelling early carbon yields helps to account for the opportunity cost (lost optionality) associated with irreversibly 'locking-in' land use to permanent forestry, and provides an additional insurance buffer against the physical reversal risks inherent to biological sequestration (such as bushfires, disease or drought).

Solve boundary: Although the foundational datasets within LUTO2 cover the entirety of the Australian continent, the model's active 'solve boundary' is strictly constrained by land tenure. LUTO2 does not project or allocate optimised land-use transitions on public lands or Indigenous-controlled estates but does consider their impacts on parameters such as water use and biodiversity. Holding public and Indigenous lands static may underrepresent the broader national potential for coordinated, cross-tenure conservation and carbon strategies. Urban centres and some other areas dedicated to non-agricultural land uses (such as mining) are also excluded.

Underlying datasets: LUTO2 integrates several major national datasets, including the Land Use of Australia map and Agricultural Census data from the Australian Bureau of Statistics. Any existing limitations in the scale, accuracy, resolution, or currency of these national datasets will naturally carry over into LUTO2's scenarios.

In particular, LUTO2 currently uses ABARES' 2010 Land Use of Australia map as a baseline (ABARES 2016a). At the time of LUTO2's development, this map was the most compatible baseline for the model's extensive ensemble of other agricultural and economic input datasets. In these scenarios, most changes in land use and management are only enabled from 2020 onwards.

While LUTO2's input datasets will continue to be updated and refined, this set of inputs was assessed as appropriate for exploring plausible futures for Australian land use by mid-century. Actual changes in land use that have occurred between 2010 and the present day are unlikely to materially alter the broad strategic interpretation of the ways patterns of land use in Australia could transition over time, or the comparisons between sensitivities. However, they do have some impact on the timing of modelled change and could lead to over- or underestimates of the overall amount of change occurring.

System-level optimisation: LUTO2 is fundamentally designed to optimise land-use transitions at the macro, system-wide level; it is not intended to prescribe or evaluate decision-making at the scale of an individual property. The model operates by balancing complex, scenario-specific temporal and spatial interdependencies across the entire Australian land and agricultural system. Consequently, localised land-use transitions projected by the model are often primarily driven by these broad, systemic shifts rather than localised factors alone.

Resolution and highly localised outputs: LUTO2's spatial resolution operates on a fixed grid of 1.1 km² cells, meaning that its reporting outputs do not specify sub-cell locations. The model can support input datasets at a higher resolution and allows uptake of multiple land uses in the same grid cell, but spatial outputs are reported as an average for each grid cell. This means LUTO2 is not designed to pinpoint exact locations of activities within properties, and it is intended to be used alongside localised ecological expertise and fine-scale assessments. Where high-resolution assessments exist, these ecologically sensitive regions can be incorporated into the LUTO2 framework as spatial constraints or 'no-go' areas, ensuring that broad-scale planning respects local environmental realities.

Biodiversity principles: Given the inherent complexity in modelling biodiversity, multiple ways of incorporating and weighting aspects of biodiversity are possible. The presented scenarios focus on a broad restoration target, rather than efforts to protect and restore habitat for specific Matters of National Environmental Significance. Separate Climateworks and Deakin University modelling will explore individual species and ecological community targets, including region-specific biodiversity priorities, and some of LUTO2's additional biodiversity target capabilities are detailed in Appendix 2.

Hurdle rates: In modelling land use transitions, LUTO2 does not incorporate financial 'hurdle rates' (the minimum expected rate of return a landowner typically requires before committing to a systemic change). Instead, the model partially accounts for the practical friction of change by embedding upfront transition costs, specific to each combination of initial and subsequent land use. These parameters are informed by empirical agricultural data and represent realistic estimates of the capital required to execute various land use shifts across Australia. While these specific transition costs ground the model in financial reality, the absence of hurdle rates means LUTO2 will generally reflect a more fluid and responsive land market than exists in practice.

Protection of existing land: The biodiversity targets in LUTO2 primarily focus on ecosystem restoration rather than conservation; however, protection of existing habitat is implicit in some of the modelling choices. Since LUTO2 does not currently permit change of land use or management on public or Indigenous lands, it is implicitly assumed that these lands are maintained in their current state. Furthermore, the restoration targets in these scenarios for the *Australia's land use future* report are binding to the point that LUTO2 generally does not switch unallocated natural lands within its study area to agricultural land uses.

Similarly, LUTO2 does not model avoided land clearing scenarios, with only greenhouse gas removals from active sequestration contributing to greenhouse gas reduction targets, and the exclusion of avoided emissions from the land sector in both historical and projected emissions data.

Conclusion

This technical report outlines the assumptions and methodology used to produce the *Australia’s land use future* report published in May 2026.

Climateworks and Deakin University are constantly updating assumptions and improving the modelling methodology to reflect the latest research and data. This includes aligning with the results of other sector-specific modelling exercises, such as any updated results from the AusTIMES model.

The design, development and modelling of scenarios is a dynamic process, and Climateworks and Deakin University will continually review and refresh our published scenarios over time. Climateworks welcomes feedback, inquiries and data requests, also welcoming suggestions for data sources that may be used to improve modelling.

For suggestions or access to more information, we encourage you to reach out at info@climateworkscentre.org.

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Appendix 1: Input data layers and soft-linking with AusTIMES

Input data layers

LUTO2 integrates a range of baseline spatiotemporal data layers related to agricultural production, process-level emissions, biodiversity, soils, and water yield, and applies them to land use maps.

Historical land use (baseline land use map)

- National Land Use Map (NLUM) (ABARES 2016a)

Agricultural commodities

- Agricultural commodity prices, crop and livestock yields (Australian Bureau of Statistics AgCensus data)
- Agricultural production costs and transition costs between land uses (Australian Bureau of Statistics AgCensus data)
- Irrigation status and water requirements
- Climate change impacts on yield (Global Agro-Ecological Zones [FAO n.d.])

Emissions and sequestration

- Carbon sequestration potential via reforestation of above-ground biomass, below-ground biomass and soils (FullCAM modelling, Soil and Landscape Grid of Australia)
- Agricultural GHG emissions (for CH_4, N_2O, CO_2)
- Carbon emissions from fire (SavBAT 3 model)

Biodiversity

- Landscape connectivity (DCCEEW's National Connectivity Index 2.0)
- Habitat condition (Habitat Condition Assessment System version 3.1)
- Species of National Environmental Significance (SNES), and the Ecological Communities of National Environmental Significance (ECNES), and all Matters of Environmental Significance (MNES) datasets
- Pre-1750 Major Vegetation Groups (MVG) and subgroups (MGS) (Native Vegetation Information System [NVIS 7.1])
- Maxent climate refugia (future species habitat suitability) modelling, defining the probability of occurrence for each year from 2010 to 2100 under four climate change scenarios (RCP2.6, 4.5, 7.0 and 8.5) (Archibald et al. 2024)

Water

- Water yield data from the InVEST® hydrological modelling (Natural Capital Project 2025)
- Water thresholds, water use by catchment and irrigation water availability, dry-land agriculture/irrigated land map

- Climate change impacts on evapotranspiration – Priestley Taylor method

Climate change impacts

- WorldClim climate data layers (Coupled Model Intercomparison Project 'CMIP6') climate scenarios from 8 global climate models (GCMs)

Agricultural productivity

- Largely aligned with historical estimates (ABARES 2025b), including heterogeneity between dryland and irrigated agricultural lands

Soft linking LUTO2 with AusTIMES

Constraints lie at the heart of decarbonisation and sustainability optimisation modelling. Within LUTO2, many of its constraints are representations of normative 'targets' established by governing bodies to realise societally-beneficial objectives. To ensure internal consistency of the scenario narrative and the optimisation environment, we have aligned constraints and assumptions across both LUTO and AusTIMES.[20] The key parameters for alignment include the carbon budgets, macroeconomic assumptions, certain techno-economic assumptions and agricultural production growth patterns.

TABLE 8: PARAMETERS ALIGNED ACROSS LUTO2 AND AUSTIMES

PARAMETER NAME	PARAMETER DESCRIPTION
Carbon budget	Budget amounts correspond to Australia's commitments under the Paris Agreement and the commonly-applied 'fair share' allocation for Australian action.
Macroeconomic assumptions (productivity and population growth rates, sectoral demand levels)	Macroeconomic assumptions form the base-case understanding of each model's simulated futures. Productivity and population growth rates directly influence demand across sectors.
Techno-economic assumptions (technology build rates, autonomous efficiency improvements, cost of deployment, technology options**)**	These parameters refer to the micro-level assumptions that constrain model decisions, such as uptake in technologies or changes in land use. Techno-economic assumptions are imposed to enable more realistic decisions by the model.
Agricultural production	Commodity-level agricultural production growth is aligned across both models to ensure energy demand is consistent with land use requirements. This consistency check extends to including the implied agricultural inputs required to produce sufficient demand for biofuel products such as biokerosene and biodiesel to meet the demand specified by AusTIMES' energy use mix.

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[20] AusTIMES is an energy systems model co-developed by Climateworks Centre and CSIRO. Refer to our Decarbonisation scenarios 2023 modelling and assumptions report for more details (Climateworks Centre 2023b).

Appendix 2: Additional LUTO2 capabilities

Additional biodiversity target capabilities

In illustrating nature-positive, Paris-aligned pathways for Australia's landscapes, the scenarios for the *Australia's land use future* report focused on a broad restoration target. While this target is broadly indicative of GBF Target 2, LUTO2 has also been designed to represent the following GBF targets.

GBF Target 3

LUTO2 can reflect elements of the land-based component of GBF Target 3 by taking into account ecosystem representativeness when prioritising areas for restoration where less than 30 per cent of the biodiversity value remains. To reflect GBF Target 3, LUTO2 can incorporate targets that ensure that 30 per cent of the area of each of the Major Vegetation Groups and subgroups (using NVIS 7.1 data), or of each bioregion under the Interim Biogeographic Regionalisation of Australia (IBRA), is under restoration or conservation-aligned land uses by 2030, by contribution weighted area LUTO2 does not currently directly model mechanisms to protect land, such as covenants.

GBF Target 4

LUTO2 can operationalise GBF Target 4 using Matters of National Environmental Significance (MNES) datasets for threatened species (SNES) and/or ecological communities (ECNES). Users can select MNES and climate refugia habitat type combinations, and apply conservation and restoration targets for species and ecological communities' habitat areas (via contribution-weighted area), to reduce species loss in the model.

GBF Target 8

GBF Target 8 is incorporated through the climate refugia species habitat modelling of Archibald et al. (2024) for prioritising areas for restoration (which is also used for prioritising areas for restoration under GBF Target 2 in the scenarios in the Australia's land use futures report.

Renewable energy land use module

LUTO2 is able to explore strategies to reduce trade-offs between renewable energy infrastructure build-out, biodiversity outcomes and the economic security of agricultural communities. Renewable energy modelling is not included in this report, but will be the subject of future Climateworks analysis.

The renewable energy module includes annual transmission mapping and technology-specific spatial estimates for capital, operational and maintenance expenditures from 2025 to 2050.[21]

LUTO2's renewable energy module includes two variable renewable energy (VRE) generation options for 'onshore wind' and 'utility solar'. These two options are modelled due to their critical importance to the energy transition as well as their measurable land requirements. Their inclusion enables trade-off analysis of the spatial distribution of solar and wind farms under different renewable energy generation demands, internalising the costs to biodiversity and agriculture. To limit impacts on critical areas for biodiversity, a biodiversity risk spatial layer using granular biodiversity value data from the Melbourne Biodiversity Institute is incorporated. This layer informs 'no-go' areas for energy development, containing critical habitat for threatened species.

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[21] The renewable energy spatial layers were developed by ANU's 100% Renewable Energy Group reflecting the infrastructural cost assumptions and transmission development timelines defined by AEMO's 'Step Change' scenario optimal development path.

TABLE 9: OVERVIEW OF LAND MANAGEMENT SOLUTIONS AVAILABLE IN LUTO2

RENEWABLE ENERGY TECHNOLOGY	RELEVANT SUSTAINABILITY AND ECONOMIC INDICATORS	RELEVANT COHABITATION LAND USES
Onshore wind: installation and operation of on-land wind turbines for the purposes of generating electricity.	Electricity generation (MWh), expected revenue (A$), capital expenditure (A$/MW), operational expenditure (A$/MWh), agricultural yields/productivity, biodiversity contribution score	Dairy, sheep, cattle, intensive cropping
Utility solar: installation and operation of grid-scale, utility solar panels for the purposes of generating electricity.	Electricity generation (MWh), expected revenue (A$), capital expenditure (A$/MW), operational expenditure (A$/MWh), agricultural yields/productivity, biodiversity contribution score	Dairy, sheep, cattle, some cropping & horticulture

The module focuses on the potential for agriculture to co-exist with renewable energy generation. Specifically, it allows for the model to cohabitate different agricultural land uses with electricity-generation technologies. The cohabitation includes appropriate multiplier impacts to yields, aggregate revenues, biodiversity contribution scores, and installation and ongoing maintenance costs. These effects are applied at the commodity-technology combination level, whereby different agricultural commodities and VRE technology combinations feature uniquely determined impacts according to the logistical realities of their operations. The multipliers were informed by industry research and reviews of academic literature.

Alongside the multiplier effects, the module also includes spatially defined variables for each VRE technology that inform the relative effectiveness of generation across the country. The key data inputs are shown in Table 10.

TABLE 10: KEY SPATIALLY DEFINED VRE DATA INPUT PARAMETERS IN LUTO2

PARAMETER NAME	PARAMETER DESCRIPTION
Establishment cost ($/ha)	Upfront costs associated with establishing VRE generation assets. This includes the upfront capital expenditure, labour installation costs, as well as other required costs such as regulatory, permitting and grid connection costs (2025–2050).
Operating and maintenance (O&M) costs ($/ha/yr)	Recurring costs associated with operating and maintaining VRE assets. Cost drivers include vegetation management, module cleaning, corrective or preventative maintenance, and structural and electrical inspections (2025–2050).
Annual expected electricity prices ($/kWh)	Time series state-based estimated electricity costs resulting from achieving a grid build-out defined by the AEMO 'Step Change' scenario (2025–2050).
Annual expected transmission map	Spatial layer reflecting the projected build-out of the national electricity grid in line with AEMO's 'Step Change' scenario.
Capacity factor (%)	Percentage factor that measures how often a VRE asset operates at its maximum potential. For 'utility solar', this factor is derived from dividing the long-term annual expected output ('specific photovoltaic power output' [PVOUT] from Global Solar Atlas) by the number of hours in a year. 'Onshore wind' data is sourced directly from the Global Wind Atlas ('Capacity factor - IEC Class II').
Distribution loss factor (%)	Percentage factor measuring the expected electricity lost as heat due to technical resistance from distributing electricity across distribution networks. These loss factors are estimated using projections for electricity load demand centres and are applied as penalties to reduce the expected generation per hectare.

The implementation of both 'utility solar' and 'onshore wind' into the model enables trade-off and opportunity analysis for meeting Australia's existing agricultural and environmental objectives alongside generating sufficient renewable energy to enable the national energy transition.

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