The Land Use Trade-Offs model v2 (LUTO2)

Summary

+ The Land Use Trade-Offs model v2 (LUTO2) is a world-leading spatial model that maps the best way to use and manage land in Australia to meet climate and biodiversity targets without compromising economic growth and food and water security.
+ LUTO2 is open source and has been developed through a collaboration between Deakin University and Climateworks Centre, with research contributions from CSIRO.
+ No other model has LUTO2's combination of spatial granularity and sophisticated analytical capability to analyse the complex interactions between climate impacts and mitigation, biodiversity, water use, agricultural production and food systems.
+ LUTO2 equips policy-makers, target-setters and regional planners with insights to envision what a sustainable, resilient future looks like for Australia's land and agriculture sector and what changes are required to achieve this future.

The importance of spatial modelling

Competition between different land uses is a global challenge. Even in a country as vast as Australia, the land and agriculture sectors must balance increasing food, fibre and energy production with the need to protect ecosystems and restore nature. As a significant source of emissions, agriculture also needs to reduce its greenhouse gas emissions. Restoring Australia's landscapes offers significant opportunities to support climate targets by sequestering carbon dioxide through increased vegetation and healthier soils.

Australia has made national and international commitments to reduce emissions, protect biodiversity and to conserve land. Moving to more sustainable land use requires rethinking how Australia uses its land and natural resources, including how food and financial systems can support such change.

Spatial modelling is crucial for informing decision-making on using and managing land to support multiple economic, environmental and social objectives. Agricultural productivity, the potential for greenhouse gas emissions and removals, the value of biodiversity, and water availability all vary by location and interact with each other in different ways in different places – so too do the impacts of climate change.

Spatial modelling enables users to conceptualise complex geophysical, societal and economic interactions necessary for identifying trade-offs and co-benefits associated with meeting environmental and agricultural targets. This information is critical for developing nature positive net zero pathways, policies and plans for the land and agriculture sector.

LUTO2's pedigree and development

LUTO2 has been developed through a collaboration between Deakin University and Climateworks, with research contributions from CSIRO. The model is a cornerstone of Climateworks' Land Use Futures program, which aims to inform Australia's transition to sustainable food and land systems. Professor Brett Bryan of Deakin University leads the development of the modelling framework.

LUTO2 builds on the approach to land use modelling of the original LUTO model, which was developed by CSIRO for the Australian National Outlook and provided Australia's national foresighting capability for land use and sustainability. With results published in Nature in 2015 and 2017, this version of LUTO was groundbreaking in its level of sophistication in analysing land change and its impacts.

LUTO2 represents a generational leap in sophistication and functionality for national-scale land use change modelling in Australia. Enhancements to the original model include extended spatial coverage and timespan, a complete refresh of input data, additional land use and sustainability solutions, the ability to model demand-side solutions, and additional environmental indicators and reporting. LUTO2's modelling approach, indicators and solutions have been agreed upon through extensive stakeholder consultation.

How LUTO2 works

LUTO2 is an integrated land systems model that optimises land use allocation across Australia based on user-defined scenario parameters. The model enables users to explore strategies to achieve climate and biodiversity targets while meeting agricultural demand through a range of demand and supply side interventions.

The model simulates the optimal distribution of future land use and land management strategies to achieve environmental and agricultural production targets while also considering the projected impacts of climate change. The model simulates land use change for all privately owned (excluding urban) and crown lease land down to a 1 km² resolution over 4 million mapped grid cells, representing over 60 per cent of Australia's total land mass. Land use changes can be simulated annually until 2100 and are optimised according to least overall system cost or maximum individual profitability.

LUTO2 also features mixed-cell grid land use simulation. Multiple land uses can exist within each cell enabling further granularity of analysis and insights for planning at different regional levels, including by state, catchment and local government area.

Each LUTO2 simulation generates accessible, interactive and detailed land use maps and time series charts. This information supports informed decision-making by illustrating trade-offs and guides optimal land use choices based on economic cost, profitability, and environmental goals.

LUTO2's capabilities

Considers climate change effects

LUTO2 models how different land uses and management practices contribute to climate change as well as how climate change itself will impact emissions, biodiversity, agricultural productivity and water availability. Users can select between four global climate change scenarios used by the Intergovernmental Panel on Climate Change.

Considers agricultural demand and food systems

LUTO2 integrates with a demand model that forecasts Australia's agricultural production given a range of global and domestic factors. These factors include population and GDP growth of Australia's main export partners, trade-related trends, domestic and international dietary patterns, changes in food loss and waste, and shifts in feed composition for livestock.

The demand model also analyses off-land food production, including poultry, pork and aquaculture and their implications for land use and the environment. This enables analysis of the potential impacts of a range of demand-side solutions, including changing diets, enhancing the efficiency of livestock feedstocks, or substituting imports with domestically grown produce.

Optimises agricultural land uses and management practices

To meet agricultural demand and environmental targets, LUTO2 can simulate switching land use between commodities. It does this while considering transition costs and the potential impacts of climate change on agricultural productivity and emissions.

LUTO2 also shows the impact of a range of agricultural management practices in conjunction with optimised land uses. Practices include feed supplements and manure management to reduce methane emissions from livestock; improved fertilisers to reduce nitrous oxide emissions; precision agriculture practices to increase productivity and lower energy use; and early dry season savanna burning to avoid emissions from hotter fires, with additional solutions under development.

Optimises non-agricultural and mixed land uses

Switching between agricultural and non-agricultural uses is also important to meet climate and biodiversity targets, particularly in areas of high biodiversity value and marginal agricultural productivity. LUTO2 shows optimal distribution of a number of Australian Carbon Credit Unit scheme compliant nature-based solutions, including environmental plantings in belts and blocks and savanna fire management. It also includes riparian plantings, plantation forestry and farm forestry, and bioenergy with carbon capture and storage. How LUTO2 prioritises these solutions depends on the relative strength of climate and biodiversity targets set by the user, and agricultural and water use implications. The inclusion of further land uses is under development.

Prioritises areas for biodiversity

LUTO2 draws on modelling of 10,608 plant and animal species to predict habitat suitability under multiple climate scenarios. This data is used by LUTO2 to prioritise areas for ecosystem restoration, in line with Global Biodiversity Framework (GBF) target 2: restore 30 per cent of degraded ecosystems by 2030. Work is underway to expand LUTO2's capabilities to solve for GBF targets 3 – ecosystem protection – and 4 – no new extinctions.

Considers water yield

LUTO2 is designed to consider how water availability will change over time with climate change, and how this interacts with varying water use requirements of different land uses and land management practices, in each catchment. This is important to ensure that modelled changes do not push catchments into water stress, thereby compromising water security. The effect of changes in rainfall and evapotranspiration as well as the impact of reforestation and land clearance on water yield are also quantified under all climate scenarios.

Data sources and accessibility

As an optimisation model, LUTO2 draws on a range of other models and data sources. These include: FullCAM (carbon sequestration), InVEST (water resource availability and use), GAEZ v4 (climate change impacts on agriculture), National Land-Use Map of Australia, Soil and Landscape Grid of Australia, ABS AgCensus data, WorldClim climate data layers (CMIP6), Atlas of Living Australia, and AussieGrass pasture growth model. Additional biodiversity datasets are being incorporated, including on habitat condition (HCAS), habitat connectivity (NCI), and threatened species and ecological communities.

Technical information and access

LUTO2 is contained in a Python 3 package and can be run interactively or in a scripted manner (e.g. for batch runs on a computer cluster). LUTO2 uses Gurobi as its commercial solver.

LUTO2 is freely available online on GitHub (including an example input dataset required to run the model) and is published as open source under GNU GPLv3 licence. At least 200 GB RAM with a 32 core processor is required to run LUTO2. LUTO2 can be run at different resolutions, determined by the user, which impact computational requirements and running times.

The model has been built for maximum flexibility by enabling a large number of user-defined settings.

LUTO2 is under continuous improvement to extend both its code and data, with new functionality coming online regularly.

Opportunities to apply LUTO2 beyond Australia

The open-source code can be adapted for other countries. However, doing so requires nationally relevant spatial datasets and spatial modelling expertise.

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Published by Climateworks Centre Melbourne, Victoria, September 2024

This publication can be downloaded at: www.climateworkscentre.org

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Co-founded by philanthropy and Monash University, Climateworks Centre is an independent not-for-profit working within the Monash Sustainable Development Institute.