The Land Use Trade-offs Model

THE LAND USE FUTURES PROGRAM

The global food system now accounts for around 30 per cent of total human-induced emissions and is a key driver of climate change (Crippa et al 2021). Australia's international competitiveness in many agricultural markets will also be challenged by the warming climate and changing weather patterns.

Moving to more sustainable food and land use systems requires redesigning how food production systems utilise land and natural resources, as well as changing consumption patterns. This requires an understanding of the transformative pathways that would result in a sustainable land use future and a deeper understanding of the impact of different choices for land use. Managing land for one type of use has impacts on other parts of the system, so decision-makers face critical choices about how lands are used to support people and food production, while also meeting climate and broader sustainability goals.

The Land Use Futures program is working to untangle the complexity of the food and land use system in Australia and demonstrate what changes in production and consumption are needed for the land sector to achieve climate goals whilst minimising trade-offs and maximising co-benefits.

ClimateWorks has partnered with Deakin University and CSIRO on Land Use Futures to undertake analysis using the Land Use Trade-offs, or LUTO, model. The model has groundbreaking capabilities to simultaneously consider the potential impact of land use practices across the entire continent of Australia, as well as potential changes in domestic and overseas demand for agricultural products.

The LUTO model is also novel in its ability to measure this potential impact across a comprehensive set of goals, so the consequences of food and land use trends can be understood across environmental, economic and social goals.

THE LAND USE TRADE-OFFS (LUTO) MODEL

Modelling helps decision-makers understand complex systems. Models don't attempt to predict what will happen in the future, rather they quantify the potential costs and benefits of different actions, as well as the potential trade-offs and synergies between these actions. This provides insights into how particular actions will influence pathways and outcomes, supporting experts, policymakers, land managers and businesses to create more sustainable plans, accounting for future uncertainty.

The Land Use Futures program is using the LUTO model to make very detailed projections representing how Australia's landscape could change in the future, depending on specific economic, social and environmental goals, conditions, and policy settings.

LUTO uses detailed historical data to model the potential future competition between different agricultural commodities (i.e. what is most profitable to grow or breed where), given demand for food, feed and sustainability outcomes.
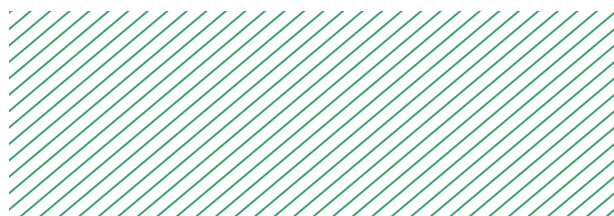
The model provides an understanding of the environmental and economic trade-offs of meeting projected demands for agricultural commodities, at both domestic and international levels. LUTO can help us answer questions like:

+ Can Australia meet future global and domestic demand for agricultural production?

+ What are the potential environmental impacts of increasing demand?

+ Can Australia meet carbon sequestration targets through planting trees to help progress the goal of net zero emissions, and also meet global and domestic demand for agricultural production?

+ How do changing global and national dietary preferences influence what types of crops and livestock are grown in Australia?

+ How do future environmental conditions and the availability of resources, such as water, influence what types of agricultural commodities are grown in particular parts of Australia?

+ How is Australia's natural plant and animal biodiversity impacted under different environmental and economic conditions and changing land use in the future?

HOW LUTO WORKS

LUTO is a spatial model, meaning it produces a map that represents the physical arrangement of land uses in Australia. The model determines the potential arrangement of land uses in a way that maximises the achievement of environmental, economic and social goals.

The model covers the entire land mass of Australia at a spatial resolution of 1km² 'pixels', presenting how land is managed and used for each pixel.
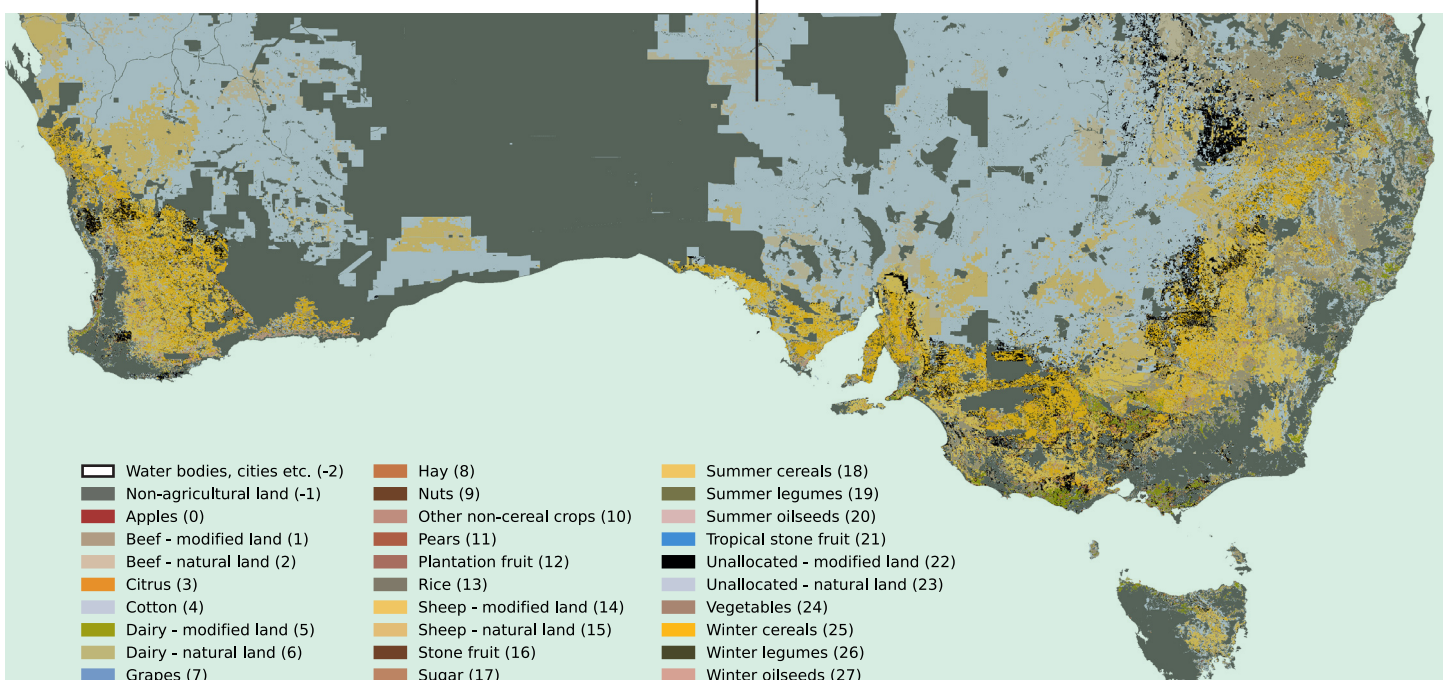
It includes both rainfed and irrigated versions of 28 agricultural land use types, as well as a number of alternate land use and management solutions designed to either increase productivity, reduce resource use, or mitigate environmental harm. Broadly, the land use types modelled in LUTO are:

+ Conservation of natural lands, including land for public and private conservation and areas of Traditional Ownership and use.

+ Ecological restoration, carbon plantings, riparian restoration, and belt plantings.

+ Bioenergy with carbon capture and storage (BECCS).

+ Unallocated agricultural lands, allowing for agricultural expansion or cessation.

+ Livestock production, such as beef, dairy and sheep grazing.

+ Cropping, such as cereals, legumes, oilseeds, rice, and sugar.

+ Horticulture/viticulture, such as apples, citrus, stone fruit, and grapes.

+ Production of chickens, eggs, and pigs.

+ Other intensive land uses, like urban areas, forestry and mining.

LUTO models these land use types by aggregating data at the 1km² local level, hence is not designed to recommend or predict changes in practices at the individual farm scale. Instead, it provides a picture of productivity and sustainability at the catchment, regional, state and national scale.

LUTO can produce maps that represent the potential physical arrangement of different land use types

| Water bodies, cities etc. (-2) | Hay (8) | Summer cereals (18) |
Non-agricultural land (-1)	Nuts (9)	Summer legumes (19)
Apples (0)	Other non-cereal crops (10)	Summer oilseeds (20)
Beef - modified land (1)	Pears (11)	Tropical stone fruit (21)
Beef - natural land (2)	Plantation fruit (12)	Unallocated - modified land (22)
Citrus (3)	Rice (13)	Unallocated - natural land (23)
Cotton (4)	Sheep - modified land (14)	Vegetables (24)
Dairy - modified land (5)	Sheep - natural land (15)	Winter cereals (25)
Dairy - natural land (6)	Stone fruit (16)	Winter legumes (26)
Grapes (7)	Sugar (17)	Winter oilseeds (27)

UPGRADES TO MODELLING CAPABILITIES

The original version of LUTO modelled the competition between agriculture and a range of alternate land uses based purely on profitability in Australia's intensive agricultural zone (approximately 800,000km^2). During 2019-2021, the LUTO model underwent a substantial upgrade to include all of continental Australia (approximately seven million km^2) and to transform it into a 'demand-driven' model.

This is a fundamental shift in the modelling approach and capability because it enables different agricultural land use types to 'compete' based on what mix of food and fibre is demanded by consumers within Australia and for export.

Some of the key upgrades to modelling capabilities during 2019-2021 have included:

+ The incorporation of groundbreaking research and analysis on predicting the future climate suitability for 10,608 species (1,356 terrestrial vertebrates and 9,252 vascular plants), which represents over half of the country's vertebrate species and over a third of plant species.

+ An update of the model's climate change projections to the use the latest World Climate Research Program (CMIP6) data.

+ The addition of more than ten sustainability indicators, to understand the impacts of change across an entirely new suite of indicators that consider multiple socio-economic and environmental components of sustainability. These include indicators measuring impact that align to relevant SDGs and 'planetary boundaries' like carbon sequestration, food loss and waste, biodiversity, water quality, soil health and productivity, among others.

+ The addition of over 40 new solutions (actions or land management practices that can be undertaken), and the capability to model intensively produced protein (pork, poultry, aquaculture) and novel protein sources (such as lab meat and mycoprotein).

+ Water extraction limits can now be applied on all water stressed catchments, enabling the model to account for potential limitations in water availability for the environment and for agriculture.
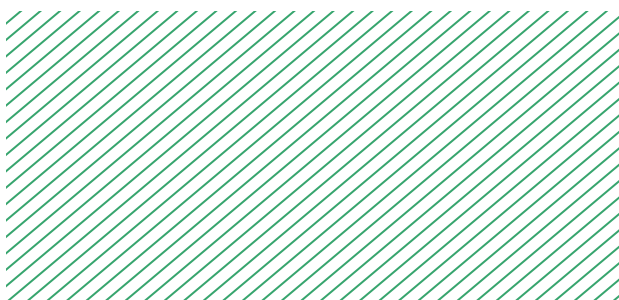
DATA SOURCES AND ACCESSIBILITY

LUTO integrates data from a range of sources. This includes research undertaken in-house by the Land Use Futures team at Deakin University, CSIRO and ClimateWorks, as well as a range of other publicly available databases – the National Land-Use Map of Australia, the Soil Grid of Australia, Australian Bureau of Statistics AgCensus data, the UN Food and Agriculture Organisation, and the WorldClim climate data layers, among many others. LUTO also employs other models in order to create the data layers required for Land Use Futures analysis including UseTox, InVeST, ANUCLIM, Maxent, FullCAM, the RUSLE, and other models.

The LUTO model is an open-source model, which enables it to be used, adapted and tested by other researchers and decision-makers. The model will achieve maximum impact if it is freely available for use by anybody, rather than remaining confidential or licensed to a particular institution. Open source coding fosters innovation, promotes transparency of the methodology and assumptions, and enables the broader scientific community to leverage and extend the work.

WHAT THE LAND USE FUTURES PROGRAM WILL LEARN FROM THE LUTO MODEL

The Land Use Futures program has developed 'scenarios' to explore using the LUTO model, drawing on stakeholder perspectives. A scenario is a narrative about what might happen in a particular future, with quantitative and qualitative information defining that future. Multiple scenarios can be modelled to understand the different impacts of a set of choices and aspirations for the future. Scenario modelling and planning is a well established method to assist in the creation of robust future plans.

The scenarios modelled by the Land Use Futures program explore different combinations and uptake of societal shifts (such as consumer preference for sustainable consumption) and innovation (such as rapid technological advancements) to create distinct futures. The LUTO model will compare the scenarios with a 'business as usual' scenario, which models a future in which we continue on current trajectories. In particular, it will measure which actions or combinations of actions have the highest impact and how far this impact takes Australia towards achieving future environmental, economic and societal goals or outcomes. Examples of the types of actions we are modelling include:

+ A range of farming practices, such as precision farming, crop rotations, pasture cropping, improved irrigation efficiency, shelterbelt planting, digital agriculture and ecological grazing.

+ Conservation-focused land management practices, such as expansion of protected areas and restoration of riparian areas.

+ Land-based carbon storage to assess the ability of the land sector to play a role in achieving net zero emissions while still meeting demand for agricultural products.

+ Reduced food loss and waste.

+ A range of shifts in dietary patterns, including shifts in consumption of particular protein sources, including novel or alternative proteins.

Modelling results will help those working in the land use sector understand implications of potential future choices and priorities for Australia's food and land use system. The outputs of the model will provide detailed information about the environmental outcomes that could result in each scenario, such as soil health, plant and animal biodiversity, water use, water quality, and carbon sequestration. This information is a tool to help grapple with the consequences of each potential future we could move towards, and can guide choices to maximise positive outcomes.

For example, insights can be gained about where it is most profitable to grow specific agricultural commodities given future climate conditions and changes in consumer demand. The model can also identify which areas may be of highest priority to preserve or restore for biodiversity conservation, informing strategic allocation of resources to maximise conservation benefits. The results will allow detailed assessment of the flow-on impact of a range of shifts in diets. An evaluation can also be made about whether Australian agricultural production can meet domestic food demand, and how domestic and overseas demand may impact our export potential.

These insights will be of interest to policymakers, the private sector, the agricultural industry and conservation organisations, among others. While the food and land use system is incredibly complex, and cannot be predicted or controlled by a particular set of actions, this modelling exercise will offer some insight to this complexity, demonstrating what solutions might be needed alongside broader shifts and practice changes, to achieve a sustainable food and land use system.

References

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F. & Leip, A. 2021, 'Food systems are responsible for a third of global anthropogenic GHG emissions', *Nature Food*, volume 2, pp.198–209, https://doi.org/10.1038/s43016-021-00225-9

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