

Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed
☐	☒ The exact sample size (<i>n</i>) for each experimental group/condition, given as a discrete number and unit of measurement
☒	☐ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☒	☐ The statistical test(s) used AND whether they are one- or two-sided <i>Only common tests should be described solely by name; describe more complex techniques in the Methods section.</i>
☒	☐ A description of all covariates tested
☒	☐ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☒	☐ For null hypothesis testing, the test statistic (e.g. <i>F</i> , <i>t</i> , <i>r</i>) with confidence intervals, effect sizes, degrees of freedom and <i>P</i> value noted <i>Give P values as exact values whenever suitable.</i>
☒	☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐ Estimates of effect sizes (e.g. Cohen's <i>d</i> , Pearson's <i>r</i>), indicating how they were calculated

Our web collection on [statistics for biologists](#) contains articles on many of the points above.

Software and code

Policy information about [availability of computer code](#)

Data collection	No software was used to collect data.
Data analysis	Biophysical production: conducted using GrassGro version 3.4.3 (https://grazplan.csiro.au/grassgro/) (Donnelly et al., 1997; Moore et al., 1997). Gross and net emissions for Scopes 1-3 were calculated using the Sheep & Beef GHG Accounting Framework (hereafter referred to as SB-GAF, V2.2, https://piccc.org.au/resources/Tools (Lopez et al., 2023), which encapsulates Australian National Greenhouse Inventory guidelines. Spatially-explicit carbon in vegetation was modelled using FLINTpro (https://flintpro.com/), which uses algorithms consistent with the Australian National Greenhouse Gas Inventory. Biodiversity assessments were conducted using the Landscape Options and Opportunities Calculator for Biodiversity (LOOC-B, https://looc-b.farm/) based on changes in habitat condition over time. RothC 26.5 was used to model soil carbon (Coleman and Jenkinson 2014).

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

Data deposited in Zenodo. See updated data availability statement in the manuscript for URL.

Research involving human participants, their data, or biological material

Policy information about studies with [human participants or human data](#). See also policy information about [sex, gender \(identity/presentation\), and sexual orientation](#) and [race, ethnicity and racism](#).

Reporting on sex and gender	NA. Data pertaining to race, sex, ethnicity, gender or demographic group were not collected.
Reporting on race, ethnicity, or other socially relevant groupings	NA. Data pertaining to race, sex, ethnicity, gender or demographic group were not collected.
Population characteristics	NA. Data pertaining to race, sex, ethnicity, gender or demographic group were not collected.
Recruitment	Case study farmers were recruited through national advertisement through multiple channels (email and industry newsletters). Of ~115 applications, we selected those shown in the paper based on their location relative to major production zones in Australia, their willingness to engage and their production system.
Ethics oversight	The University of Tasmania Human Ethics Committee approved methods underpinning this study (Project ID 27905).

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see [nature.com/documents/nr-reporting-summary-flat.pdf](https://www.nature.com/documents/nr-reporting-summary-flat.pdf)

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	We conducted a transdisciplinary assessment of farms positioned across the southern seaboard of Australia. Our study was not intended to represent the entire farm population; instead, it was intended to intentionally select case studies according to several pre-defined characteristics (see below). Advertising was conducted by electronic industry newsletters (Meat & Livestock Weekly, South Australia Livestock Research Council and Western Australia Livestock Research Council). Of 115 applications, we selected those farms shown in the paper based on their location relative to major production zones in Australia, farm size, their willingness to engage and characteristics of their production system (self-replacing, breeder-finisher, purchase sell or mixed enterprises). Selected case study farmers completed questionnaires on their farm operations and participated in meetings to provide data and refine and sense check the modelling. Baseline farm data were collected in Word documents first completed by the farmers, then refined online with researchers. Baseline information were then used to calibrate a range of modelling packages to reproduce status quo pasture and livestock production, carbon in vegetation and soils, biodiversity and profitability. To examine implications associated with interventions relative to status quo farming systems (hereafter, 'baseline systems'), we invoke data from seven real enterprises as case studies. Farms were selected across the five predominant livestock production zones in Australia (MLA, 2022). Farm area ranged between 250 ha and 7,777 ha, 41-97% of farm area was subjected to livestock grazing, and carried 950-56,000 dry sheep equivalents (DSE; Fig. 1). Baseline data was collected from each farm to calibrate a range of biophysical, economic and ecological models. Using a participatory approach, farmers co-designed interventions and co-refined model inputs to validate modelled outputs for baseline systems, including seasonal pasture growth, supplementary feed use, total animal numbers, farm areas under vegetation, timing of historical tree planting, costs and financial income. This process required several iterations between researchers and each case study farmer until final model inputs were agreed. Baseline information is detailed in the Supplementary Information of the paper (Table S1). Reference MLA 2022. Sheep numbers – as at June 2021 Natural Resource Management Region. Available: https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/trends--analysis/fast-facts--maps/mla_sheep-distribution-map-
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	june-2021_v02-final.pdf [Accessed 16 June 2025].
Research sample	Please see above.
Sampling strategy	Please see above.
Data collection	The corresponding, first and second authors collected the data using questionnaires first sent to each case study farmer. These data were checked and refined in subsequent meetings with each farmer.
Timing and spatial scale	Data were collected between January 2021 and December 2024. Farm locations are shown in Table 2 (spread across all sheep production zones in Australia).
Data exclusions	NA
Reproducibility	NA
Randomization	NA
Blinding	NA

Did the study involve field work? ☐ Yes ☒ No

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Plants

Seed stocks	NA
Novel plant genotypes	NA
Authentication	NA