Department of Primary Industries
and Regional Development

Sheep
Merino

Results Report

Climate Vulnerability Assessment

NSW GOVERNMENT

Authors

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Funding

The Climate Vulnerability Assessment has been completed as part of the Primary Industries Climate Change Research Strategy funded by the NSW Climate Change Fund.

Suggested citation

NSW Department of Primary Industries and Regional Development (2025) Climate Vulnerability Assessment sheep Results Report. https://www.dpi.nsw.gov.au/dpi/climate/climate-vulnerability-assessment/publications-and-reports/Climate-Vulnerability-Assessment-Sheep-Results-Report.pdf, accessed on [insert access date].

Acknowledgement of Country

The NSW Department of Primary Industries and Regional Development acknowledges that it stands on Country which always was and always will be Aboriginal land. We acknowledge the Traditional Custodians of the land and waters and show our respect for Elders past, present and emerging. We are committed to providing places where Aboriginal people are included socially, culturally and economically through thoughtful and collaborative approaches to our work.

TITLE: Sheep Results Report
ISBN: 978-1-76058-879-3

Table of Contents

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Introduction

Primary industries in New South Wales operate a wide variety of production systems within diverse landscapes, while facing the challenges of a changing and highly variable climate. The Primary Industries Climate Change Research Strategy invested $29.2 million in projects to help the state's primary industries adapt to climate change. As part of this work, the Climate Vulnerability Assessment undertook impact assessments for primary industries in the broadacre cropping, marine fisheries, forestry, extensive livestock, and horticulture and viticulture sectors, and for key related biosecurity risks, to improve our understanding of the impacts of climate change.

The Climate Vulnerability Assessment has delivered a consistent and state-wide understanding of climate change impacts, comparable across industries, and provided deep insights into impacts on individual primary industry sectors. This strategic information is invaluable for policymakers and industry, providing insights into 28 commodities and 14 biosecurity risks that have been deemed valuable or important to NSW.

This comprehensive assessment allows primary industries to understand the risks ahead, prepare for and adapt to any identified climate vulnerabilities, and to take advantage of future opportunities to expand production in NSW.

Purpose of this report

This report contains results for the sheep model within the Climate Vulnerability Assessment Project. It introduces the sheep industry in NSW and provides an overview of the model and a description of its key features, assumptions and exclusions. The main modelling results and findings provide insights into future climate vulnerabilities and/or opportunities and, where appropriate, the report also provides adaptation options.

Climate within NSW

The climate in NSW varies across the state, influenced by topography, weather patterns, and proximity to the Great Dividing Range and the Tasman Sea. The state's diverse climates include arid and semi-arid inland regions, humid subtropical coastal areas, temperate coastal regions and alpine areas.

The changing climate is impacting primary industries

Australia has one of the world's most variable climates, and its primary producers have always managed climate variability. Now, they are planning for and adapting to climate change arising from anthropogenic greenhouse gas emissions. These changes in long-term climate patterns at global and regional scales are adding a new dimension to the challenge of producing food and fibre in Australia. Changes in climate include increasing temperatures and alterations to rainfall patterns, alongside increasing challenges from extreme events.

The $23.1 billion sector supports economic growth and development, contributes to food security at the state and national scale and plays a vital role in biosecurity management. The limited availability of practical and targeted information on the impact of climate change on commodity productivity or the changing prevalence of biosecurity risks has limited adaptation to climate change in this sector.

The Climate Vulnerability Assessment addresses the lack of information on climate change impacts by providing comprehensive assessments specific to primary industries in New South Wales. It aims to understand climate change risks and impacts on these industries and demonstrate the value of adaptation strategies.

Projected climate change impacts

A review of research literature on the impacts of projected climate change on primary industries in Australia revealed disparities in research efforts across the primary industry sectors and in our understanding of what is likely to occur[1].

The research effort on climate change and livestock is skewed. Of the 33 studies that assess the impact of climate change on livestock in Australia, 26 were found to be focused on pastures and pastures systems rather than livestock[1]. Overall, the studies elicited a range of direct and indirect impacts for pastures and livestock. These include impacts on pasture quantity and quality, livestock production and health, the prevalence of pests and disease[2,3,4]. While these studies included parts of NSW, not all pasture regions were covered, and the impacts could not be compared and combined due to differences in research approaches and methods.

Assessing the impacts of climate change

To address these issues, the Climate Vulnerability Assessment examined the potential impacts of climate change on a wide range of economically important primary industry commodities and related biosecurity risks in NSW. This enabled us to identify those industries most at risk and so most in need of adaptation strategies, as well as those where climate change might bring new opportunities and relief from existing challenges.

[1] Darbyshire, R. O., Johnson, S. B., Anwar, M. R., Ataollahi, F., Burch, D., Champion, C., Coleman, M. A., Lawson, J., McDonald, S. E., & Miller, M. (2022). Climate change and Australia's primary industries: factors hampering an effective and coordinated response. *International Journal of Biometeorology*, 1-12.
[2] Ghahramani, A., and Moore, A.D. (2013) Climate change and broadacre livestock production across southern Australia. 2. Adaptation options via grassland management. *Crop and Pasture Science* 64(6).
[3] Nidumolu, U., Crimp, S., Gobbett, D., Laing, A., Howden, M., and Little, S. (2014) Spatio-temporal modelling of heat stress and climate change implications for the Murray dairy region, Australia. *International Journal of Biometeorology* 58(6), 1095-1108.
[4] Harrison, M.T., Cullen, B.R., and Rawnsley, R.P. (2016) Modelling the sensitivity of agricultural systems to climate change and extreme climatic events. *Agricultural Systems* 148, 135-148.

Sheep in NSW

Sheep are distributed widely throughout NSW (Figure 1), except for the wetter tropical and subtropical coastal areas due to the higher chance of parasite infection and other diseases such as footrot. There were a total of 27.1 million sheep and lambs in NSW for 2023[5].

The industry is widespread from far western NSW to the eastern tablelands. The most populated sheep regions in NSW are the Riverina, Central West, Southeast, Murray, Central Tablelands, Northern Tablelands and Western Local Land Service Regions. The sheep population in different regions of NSW is presented in Figure 1. sheep density (stocking rate) is higher in regions with climate conditions which favour productive pasture growth, for example the Central and Northern Tablelands, compared to western NSW.

Sheep production phases

Reproduction, Survivability and Feed Intake were chosen as key drivers of production performance in a sheep enterprise, because they are sensitive to climate conditions such as heat stress and chill conditions. The dates for which sheep operations will join and shear vary across NSW, so two dates were selected for this model;

- September Lambing, July Shearing enterprise, referred to as Spring Lambing;
- June Lambing, April Shearing enterprise, referred to as Winter Lambing.

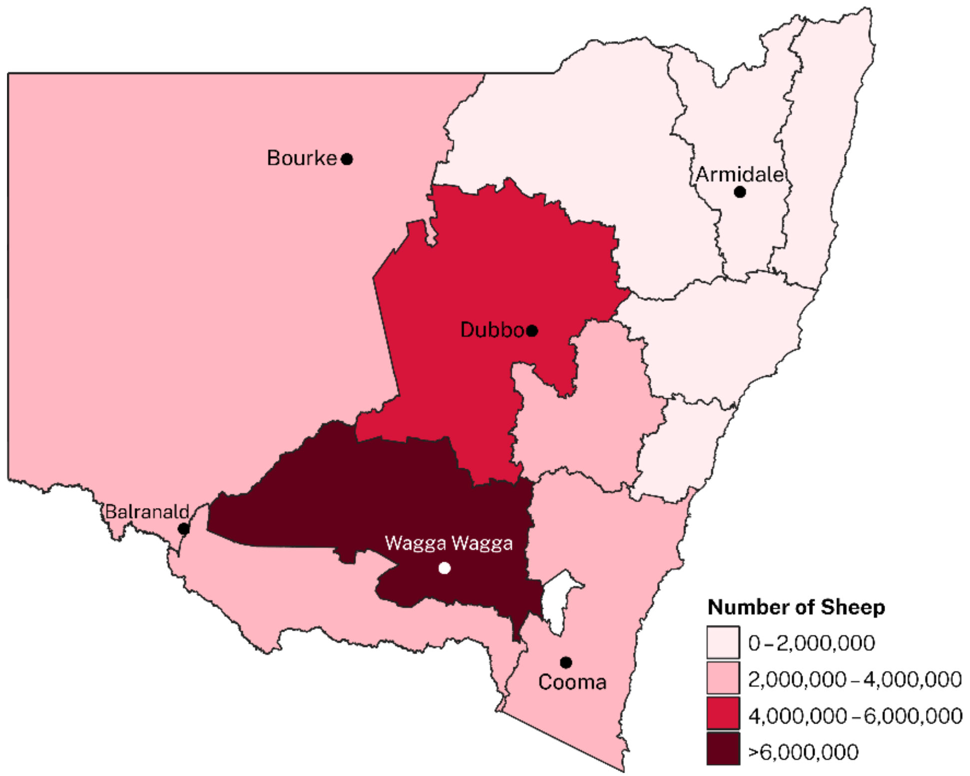


Figure 1. Map presenting the sheep population for different regions of NSW (ABS, 2021)

[5] MLA (2023). Fast Facts. Australian sheepmeat industry

Climate Vulnerability Assessment framework

The Climate Vulnerability Assessment Project was designed to provide an overview of the impact of future climate change on all stages of production for the commodities and biosecurity risks assessed. To achieve this, the project adopted a modelling approach that would produce assessments for the commodities and biosecurity risks in a consistent, and therefore comparable, way. The framework provides a rigorous, flexible and transparent process for assessing vulnerability to climate change.

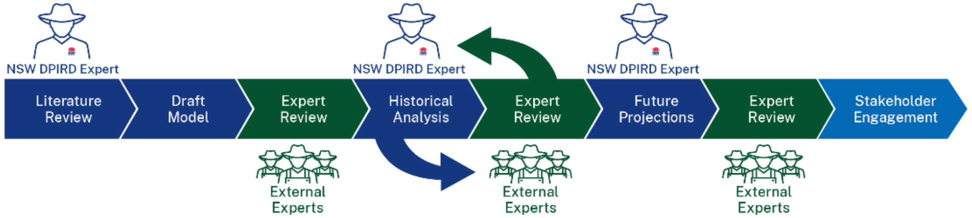


Figure 2: Outline of expert engagement in the assessment framework developed by the Climate Vulnerability Assessment Project. Internal and external experts are involved throughout the process, helping to develop and refine the model of their primary industry, sheep or biosecurity risk.

The assessment process, outlined in Figure 2, begins with a literature review, used to inform a draft model of the commodity or biosecurity risk. External experts review the model at three points during model development as part of a small focus group. The participation of experts throughout the process was critical for integrating expert knowledge into the models.

Over 100 Department of Primary Industries and Regional Development staff contributed to this process, and almost 200 external experts participated in focus groups to support the review and refinement of the models. The external experts were drawn from industry bodies, producers, academia, other governments and elsewhere.

MCA modelling approach

The steps in the framework developed for the Climate Vulnerability Assessment were designed to identify and compare the climate variables important in the production of each commodity and the survival of each biosecurity risk assessed. The chosen modelling approach, using multi-criteria analysis (MCA) models, allows knowledge obtained about these climate variables from scientific literature, expert focus group knowledge and other sources to be combined in a way that is consistent across all commodities and biosecurity risks.

A simple MCA model with customisable assumptions and exclusions (detailed below) was developed for each commodity and biosecurity risk. A hierarchical structure underpins the MCA modelling approach, and the models were developed using a combination of empirical data and expert judgment. The commodity or biosecurity risk sits at the top of the hierarchy, which is then divided into the key production phases, each of which contains the climate variables that influence that production phase.

Each life stage is weighted relative to the others to reflect the importance of its contribution to the overall success in the growth of the commodity or the survival of the biosecurity risk. The weightings were derived using the analytical hierarchy process[6] and reflect a consensus reached by the focus group experts.

[6] Saaty, T.L. (1980) The Analytic Hierarchy Process, McGraw-Hill, New York

The models were not designed as yield estimating models but as models of climate suitability. Climate suitability is defined as the extent to which climatic conditions satisfy the requirements of plant or animal growth in the absence of other limiting factors[7], and the models provide an assessment of climate suitability (ranging from unsuitable to highly suitable) for each individual climate variable and for each production phase, as well as for the overall model. Climate suitability is modelled for both historical (recent past) conditions and for projected (near future) climate to help us understand how the climate suitability for sheep may be affected by climate change

Experts reviewed the historical and future assessments and provided insights and interpretations, highlighting findings of importance for future planning. The following sections of this report provide an overview of the model structure for sheep and key results, showing important changes to future climate suitability for sheep.

For further details on the Climate Vulnerability Assessment framework, MCA models and the climate data (historical observations and future projections) used by the project, please refer to the Climate Vulnerability Assessment Methodology Report.

The project limitations and exclusions are briefly summarised to the right, and the sheep model-specific assumptions are summarised on the next page.

Project scope and exclusions

The scope was limited to the assessment of vulnerability to future climate change. The assessment captures the response of sheep to changes in future average climatic conditions. The project was designed to support policy and regional investment decisions, not provide farm-scale advice. The following were not considered:

- topography
- other biophysical parameters
- socio-economic factors

These factors should be considered alongside the project's findings when examining the ongoing or future viability at a given location.

Certain climate data were excluded due to future climate projection data limitations. Models excluded wind due to its variability on short timescales and the use of relative humidity on timescales shorter than a month. Extreme weather events such as intense rainfall, heatwaves, storms, drought, floods, and bushfires were also excluded due to their unpredictable nature and the complexities of their interaction with the climate. Future work incorporating more sophisticated future climate projections as they become available is likely to provide an improved capacity for describing the impacts of extreme weather events and climate variability.

[7] Zhao, J., Yang, X., Liu, Z., Lv, S., Wang, J. and Dai, S. (2016) Variations in the potential climatic suitability distribution patterns and grain yields for spring maize in Northeast China under climate change. Climatic Change, 137:29-42.

Overview of the sheep model

For more information about the MCA modelling used in this project, see the Climate Vulnerability Assessment Methodology Report.

Climate variables

The climate variables used in the sheep MCA model include minimum temperature (T_{min} °C), maximum temperature (T_{max} °C), and the derived chill index.

Categorising climate variables

The hierarchical structure of the MCA model (Figure 3) categorises climate variables to assess their impact on sheep. Each category (for example, a temperature between 15 and 30°C) is assigned a rating, R, between 0 and 1 that indicates how well it suits sheep, from unfavourable (R=0) to optimal (R=1).

Modules used in sheep MCA model

The sheep MCA model uses the following standardised techniques, referred to as 'modules', to produce ratings from the climate variables. Two modules were used in this model:

- **Proportional module**: examines the duration (in days) spent in each climate category during a given production phase.
- **Threshold module:** examines the number of days spent below or above a key climate threshold during a given production phase.

The ratings for each climate variable, together with the weighting assigned to each branch in the hierarchical structure and the climate data itself, produce the climate suitability index for sheep.

Sheep model assumptions

A model represents a simplified version of reality. Assumptions and exclusions simplify complex systems by reducing the number of influencing factors, enabling model development. In addition to the project assumptions and exclusions, the sheep model also contains the following exclusions:

- the model is focused on Merino sheep as this breed is the dominant breed in NSW, with approximately 66% of breeding ewes and 40% of lambs in NSW being Merinos[8].
- best practice management is undertaken.
- the livestock or pastures are free of pests and diseases.
- dates of production phases are fixed.
- adequate feed and water are available.
- specific joining and lambing dates were selected and are not necessarily appropriate for all livestock operations in NSW.

Model overview

The sheep MCA model contains 3 phenophases, 'reproduction', 'survivability' and 'feed intake'. 'Reproduction' is the highest weighted of them, representing 68% of the overall model, followed by 'survivability' (25% of the model). The phenophases are broken down into sub-phenophases. During the lambing and shearing sub-phenophases, chill index plays an important role, with climate suitability dropping as accumulated chill rises above 950.

Please note that the model was run for two sets of production dates:

- September Lambing, July Shearing, referred to as Spring Lambing;
- June Lambing, April Shearing, referred to as Winter Lambing.

These dates are indicated in Table 1.

[8] Meat and Livestock Australia and Australian Wool Innovations (2018). MLA and AWI Wool and sheepmeat Survey Report - sheepmeat. Kynetec, Kynetec.

Table 1: Production phase dates used in the sheep MCA model for Spring and Winter Lambing Enterprises.

Production Phase	Dates for a Spring Lambing Enterprise	Dates for a Winter Lambing Enterprise
Pre-Joining	14 February – 30 March	30 November – 13 January
Joining	31 March – 4 May	14 January – 17 February
Lambing	28 August – 6 October	13 June – 6 October
Shearing	14 July – 27 July	29 April – 12 May
1st Gestational Trimester	31 March – 29 May	14 January – 14 March
2nd Gestational Trimester	30 May – 28 July	15 March – 13 May
3rd Gestational Trimester	29 July – 5 October	14 May – 21 July
Ewe Feed Intake	Year Round	Year Round
Lamb Feed Intake	8 December– 28 August	23 September – 13 June
Lactation	9 September – 6 October	25 June – 22 July

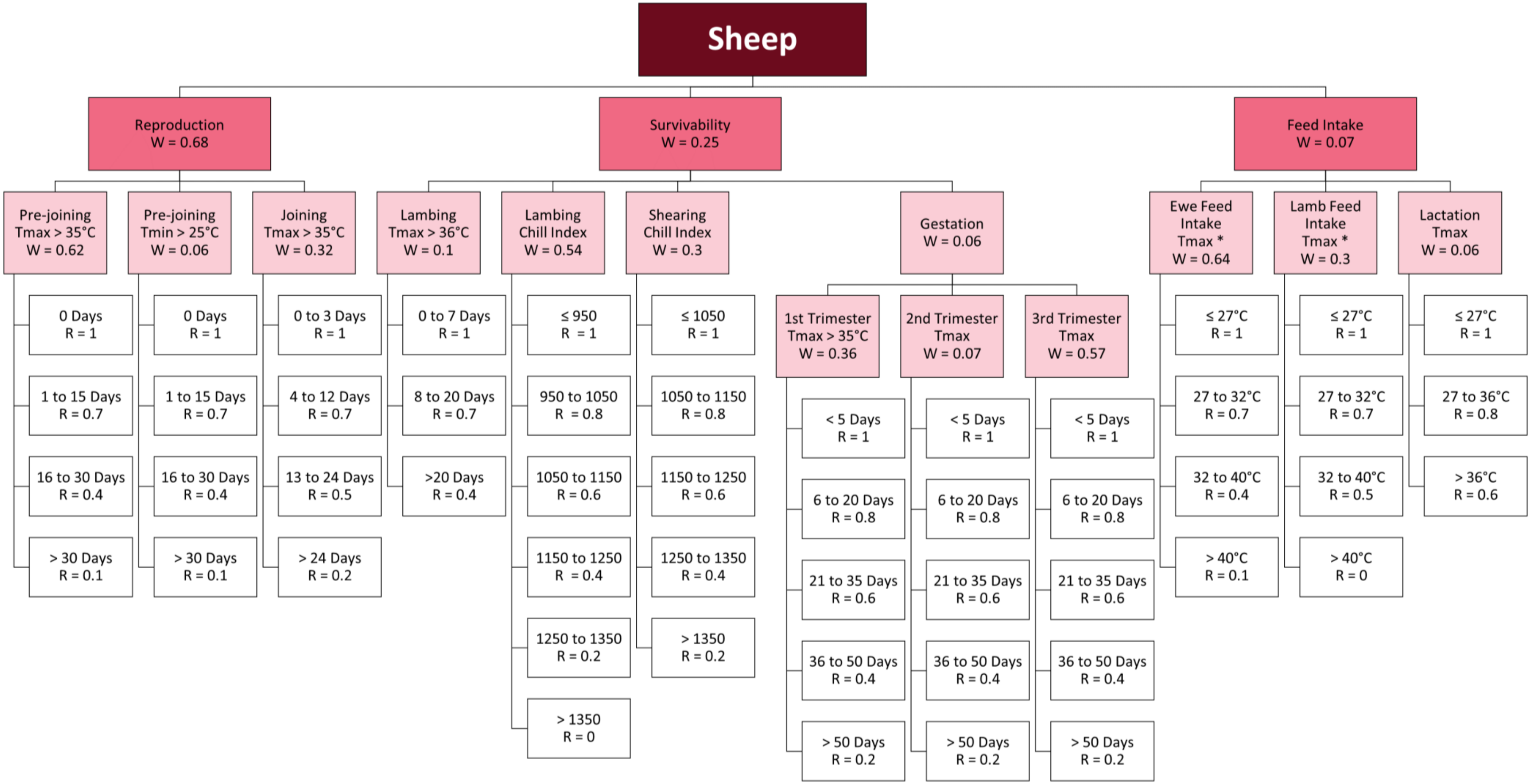


Figure 3: MCA model hierarchical structure and model components for sheep (Merino). The top-level of the hierarchy is the commodity. The second level contains the production phases identified as climate-sensitive by the literature review and expert judgment. The third level contains climate variables which affect each production phase.

Interpreting the results

The results are presented as panels of 7 maps, comparing historical climate suitability with climate suitability under the two future emissions scenarios (RCP4.5, an intermediate emissions scenario and RCP8.5, a high emissions scenario). For the future emissions scenarios, maps of change and confidence in change in climate suitability are also presented. The NSW key sheep growing regions are displayed on each map to indicate the areas where sheep are currently produced.

The historical climate suitability map shows the mean suitability for 30 years (1981 to 2010). For future projections, the mean suitability for 30 years (2036 to 2065) was calculated for 8 global climate models[9], and the median of these models was used to produce ensemble future projection climate suitability maps.

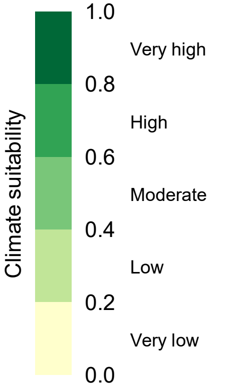


Figure 4: Colour scheme for the climate suitability maps

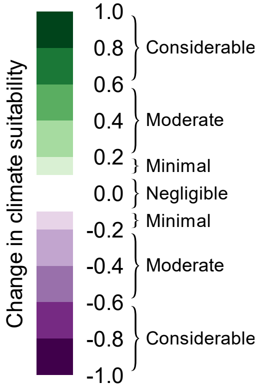


Figure 5: Colour scheme for the change in climate suitability maps

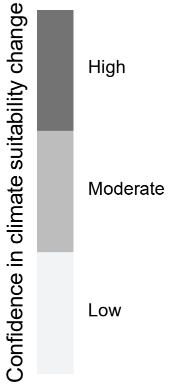


Figure 6: Colour scheme for the confidence in the change in climate suitability maps

Historical and future climate suitability maps

The 'climate suitability' maps show the climate suitability on a scale of 0 to 1. Pale yellow is very low suitability, and dark green is very high suitability.

Change in climate suitability maps

The 'change in climate suitability' maps use a green-white-purple colour scheme with 11 categories: positive change, where the future climate becomes more suitable, is shown in shades of green; negative change is shown in shades of purple. Negligible change is represented by white and occurs for values between −0.1 and 0.1; in these areas, the future climate suitability will be very similar to the historical suitability.

Confidence in the change in climate suitability maps

The 'confidence in change in climate suitability' maps represent the level of agreement across the ensemble of 8 global climate models on the direction and magnitude of change in climate suitability. The lightest shade of grey represents low confidence, and the darkest shade of grey represents high confidence.

[9] Data was sourced from Climate Change in Australia: Application Ready Data

Understanding climate suitability: a guide to map interpretation

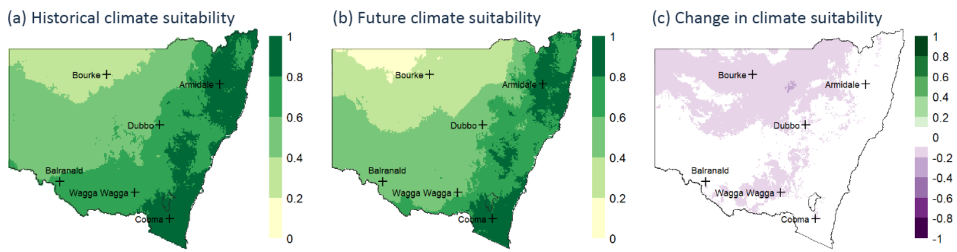
The Climate Vulnerability Assessment has strived for accuracy and clear interpretation in our data representation, particularly when there is uncertainty. The MCA models produce continuous climate suitability values. To help readers interpret the maps, these suitability values have been grouped into 5 categories between 0 and 1 (each shown in a different colour). Changes in climate suitability values are also continuous but have been grouped into 11 categories between -1 and 1. Negligible change is shown in white and is defined as -0.1 to 0.1, and the values within this range are considered uncertain. However, this categorisation can occasionally lead to our maps showing results that are not immediately intuitive. Below are two circumstances that arise, and we have described why and how this occurs.

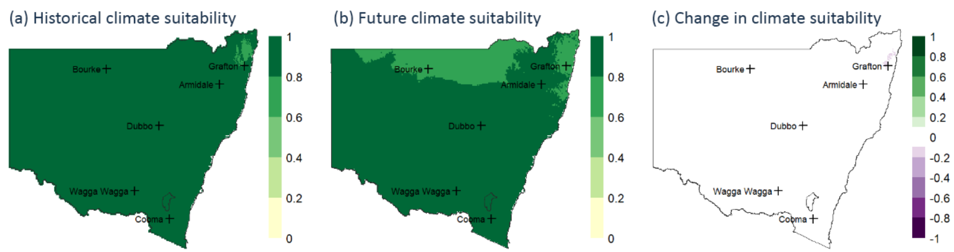
Why does the 'change in climate suitability' map show changes in some places where the historical and future climate suitability maps have the same colour? There are instances where historical and future climate suitability maps show the same category of climate suitability, yet the change in suitability maps indicates a positive or negative shift. This occurs when the climate suitability has changed, but not sufficiently to move it from one category to another.

In the example below, you can see this south of Bourke when comparing the historical, future and change maps. The climate suitability of Bourke changes from 0.35 in the historical map to 0.22 in the future map. This leads to no change in the suitability category (both maintain low suitability), but as the change is 0.13, this is categorised as minimal change and is shown in the change in suitability map in purple.

Why is there negligible change (white) on the change map in places where the historical and future climate suitability maps have different colours? Sometimes, the categories change between the historical and future climate suitability, but the 'change in suitability' maps show negligible change (white). This happens when the climate suitability changes enough to move into a different category, but the change in the value is small (less than 0.10).

For example, you can see this around Bourke when comparing the historical, future, and change maps below. The climate suitability of Bourke changes from 0.85 in the historical map to 0.79 in the future map, leading to a change from very high to high climate suitability, but as the change is 0.06, this is considered negligible.





Projected changes in climate suitability for sheep

Climate change is likely to offer both opportunities and challenges for sheep production in NSW by 2050.

This section provides a selection of key results for the sheep model. The section begins with an overview of the main impacts, vulnerabilities, and opportunities, followed by key maps from both enterprises that show notable changes. The relevant interpretation and findings are provided in text on the bottom left corner of each map panel.

Overall climate impacts

The outputs from the sheep MCA model show different climate suitability for the two enterprises that have been modelled. Spring lambing production systems are likely to continue to experience high to very high climate suitability for sheep production in 2050 under both emissions scenarios (*moderate to high confidence)*. Whilst winter lambing production systems, across most of the state, are likely to experience similar climate suitability to what has been historically experienced, the northwest of the state under the high emissions scenario is likely to experience minimal negative change in climate suitability in 2050 (*high confidence*).

Feed Intake requirements

Feed intake requirements refer to the amount and type of feed needed to meet the nutritional requirements of animals

What is chill index?

Chill index describes the impact of cold climatic conditions on lambs. It considers wind, temperature and rainfall.

Climate impacts on production phases

Climate change impacts on the NSW sheep industry are likely to affect the two main production systems of winter lambing and spring lambing in different ways.

Spring lambing

Spring lambing production systems are likely to continue to experience very high climate suitability (moderate to high confidence) (Figure 7).

- **Reproduction** is likely to experience increased heat during pre-joining (Figure 8) and joining (*moderate to high confidence*). This is likely to minimally decrease suitability around Bourke and in the northwestern corner of the state in an intermediate emissions scenario (*high* confidence) and extend the reduction in climate suitability further south and east in a high emissions scenario *(moderate to high confidence*).
- **Survivability** is expected to experience similar climate suitability across NSW to what has been historically experienced (*high confidence*). However, in a high emissions scenario suitability during lambing is expected to minimally increase in the Armidale (Figure 9) region due to reduced chill (*high confidence*).
- **Feed intake** is expected to remain similar to what has been historically experienced (*high confidence*).

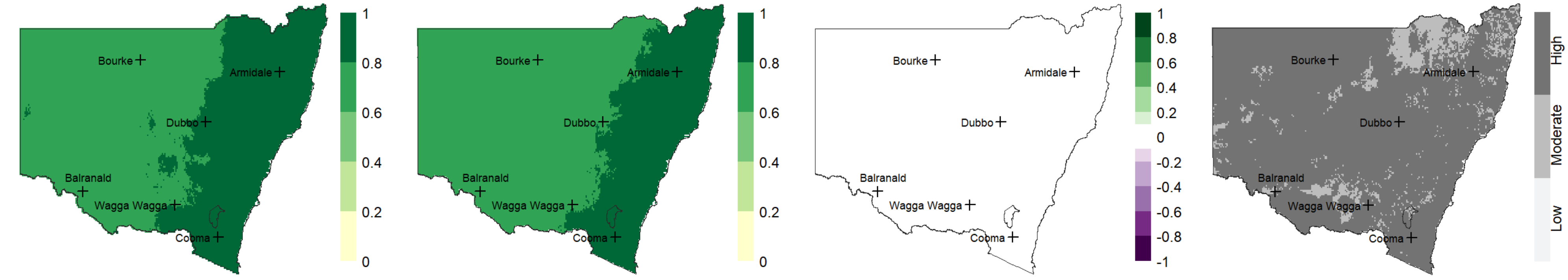
Winter lambing

Winter lambing production systems are likely to have minimal change in overall climate suitability. Overall, in central and western regions of NSW, where winter lambing is most common, the historical and future climate suitability is likely to be slightly lower than the climate suitability of spring lambing production systems (Figure 10).

- **Reproduction** is likely to experience increased heat during pre-joining (Figure 11) and joining (*moderate to high confidence*). This is likely to minimally decrease suitability at Bourke, Wagga Wagga and west of Armidale and Dubbo (*moderate to high confidence).* Under the high emissions scenario the impacts are more widespread across the state (*high confidence*).
- **Survivability** is expected to experience similar climate suitability across NSW to what has been historically experienced (*high confidence*). Gestation during the first trimester (Figure 12) is likely to experience increased heat stress (*high confidence*).
- **Feed intake** is expected to remain similar to what has been historically experienced (*high confidence*).

Sheep – Spring Lambing - Overall

Historical	RCP4.5 intermediate emissions scenario		
A) Climate suitability	B (i) Future climate suitability	B (ii) Change in climate suitability	B (iii) Confidence in change



Findings: Most of the state is likely to experience similar climate suitability to what has been historically experienced (*moderate to high confidence*), except for the north-west of the state under the high emissions scenario where there is minimal negative change in climate suitability (*high confidence*).

RCP8.5 high emissions scenario		
C (i) Future climate suitability	C (ii) Change in climate suitability	C (iii) Confidence in change

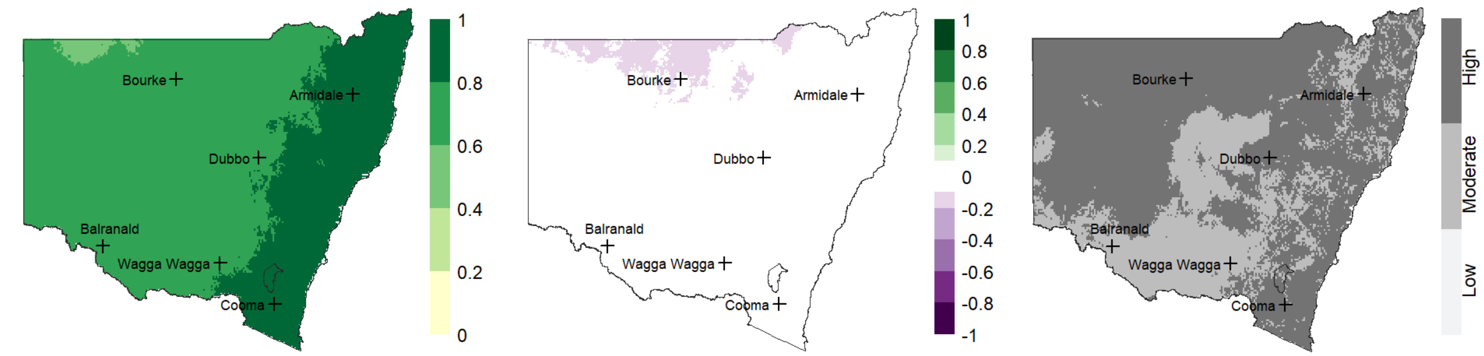
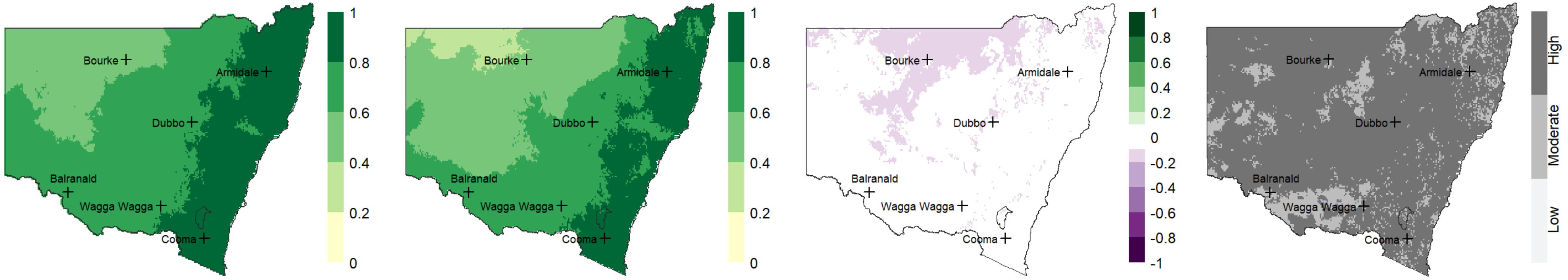


Figure 7: Overall climate suitability for sheep with spring lambing in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected future change in climate suitability as negligible (white), positive (green) or negative (purple) change, and iii) shows the level of model confidence associated with this change (low, moderate or high). Sites indicating key regions where sheep are grazed are marked by black crosses.

Sheep – Spring Lambing – Pre-Joining (Number of Days > Tmax of 35°C)

Historical | RCP4.5 intermediate emissions scenario

A) Climate suitability | B (i) Future climate suitability | B (ii) Change in climate suitability | B (iii) Confidence in change



Findings: There is likely to be minimal negative change in climate suitability across much of the state *(moderate to high confidence)*, with areas of moderate change in the central north of the state (*high confidence)* under the high emissions scenario. These changes are due to an increase in the number of days of heat stress during this time of the year.

RCP8.5 high emissions scenario

C (i) Future climate suitability | C (ii) Change in climate suitability | C (iii) Confidence in change

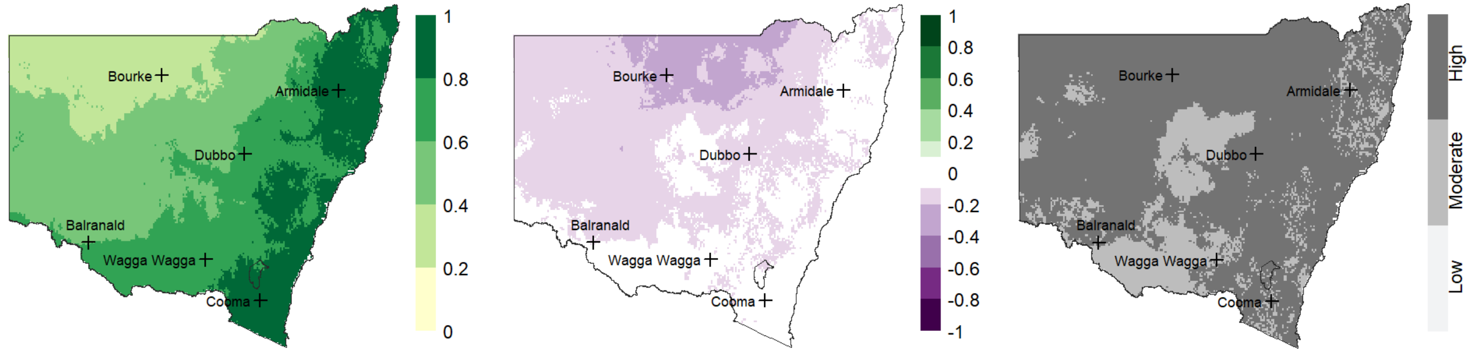
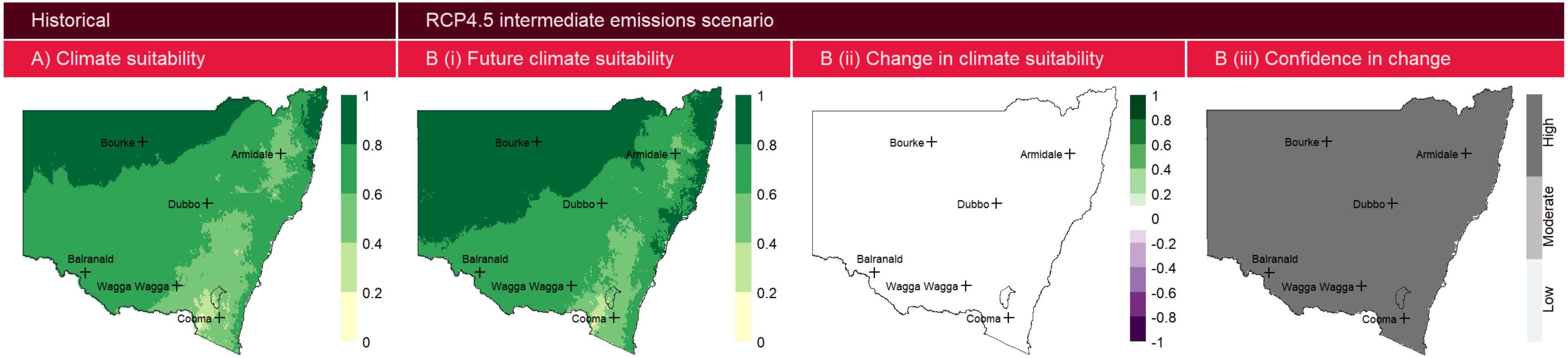


Figure 8: Climate suitability during pre-joining for sheep with spring lambing in NSW. This figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected future change in climate suitability as negligible (white), positive (green) or negative (purple) change, and iii) shows the level of model confidence associated with this change (low, moderate or high). Sites indicating key regions where sheep are grazed are marked by black crosses.

Sheep – Spring Lambing – Lambing (Chill Index)



Findings: There is likely to be minimal positive change in climate suitability around Armidale *(high confidence)*, under the high emissions scenario. These changes are due to a decrease in the chill conditions during this time of the year.

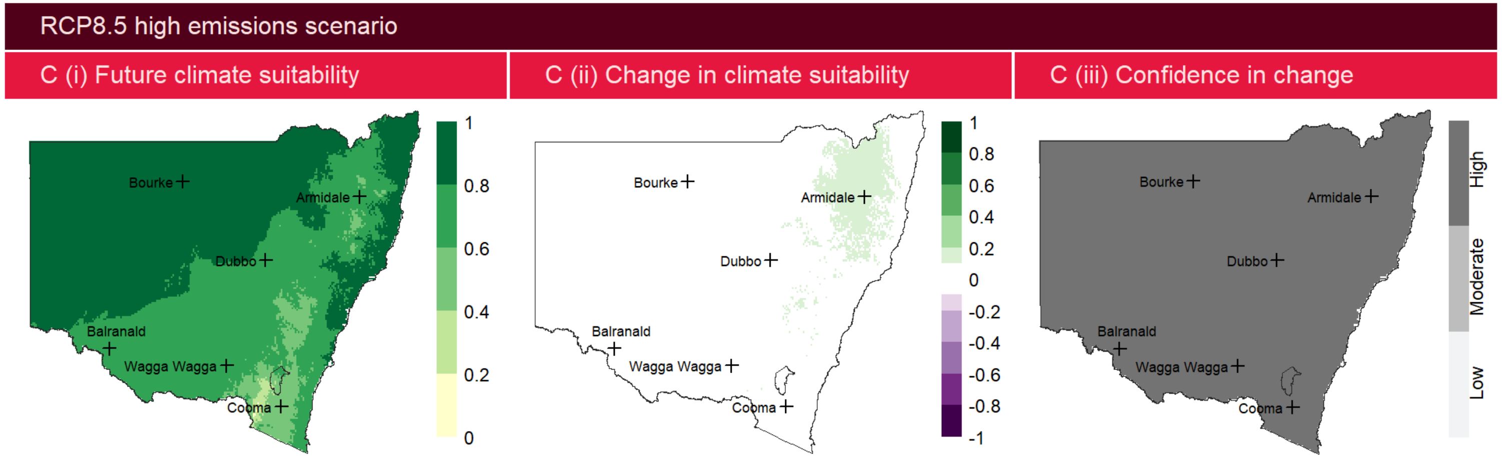
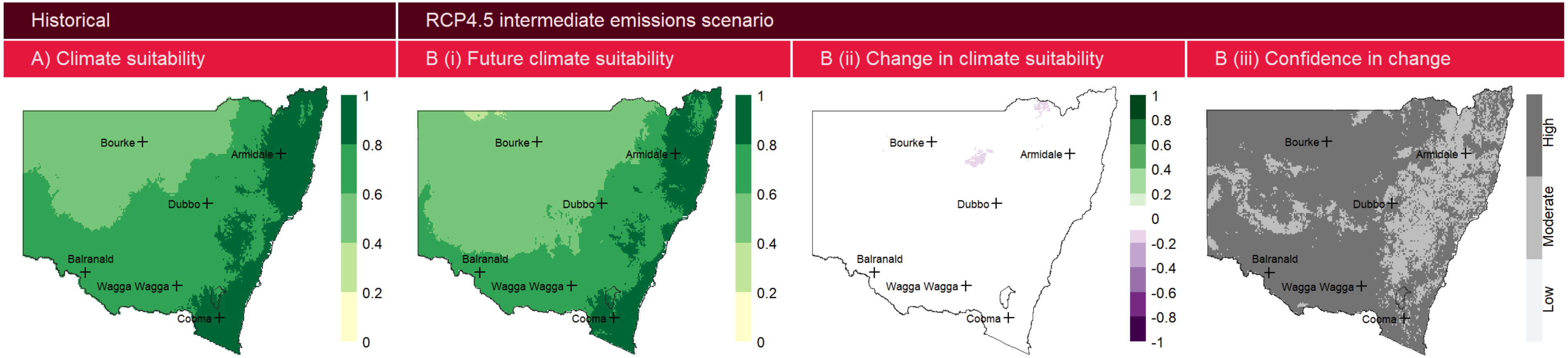


Figure 9: Climate suitability during lamb survival for sheep with spring lambing in NSW. This figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected future change in climate suitability as negligible (white), positive (green) or negative (purple) change, and iii) shows the level of model confidence associated with this change (low, moderate or high). Sites indicating key regions where sheep are grazed are marked by black crosses.

Sheep – Winter Lambing - Overall



Findings: Most of the state is likely to experience similar climate suitability to what has been historically experienced (*moderate to high confidence*), except for the north-west of the state under the high emissions scenario where there is minimal negative change in climate suitability (*high confidence*).

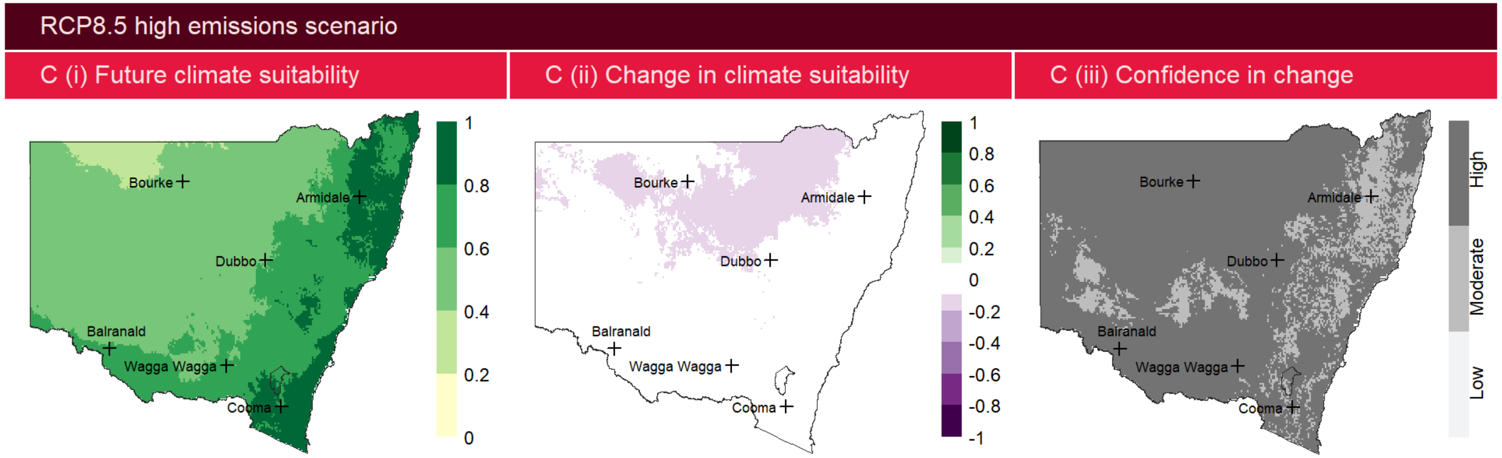
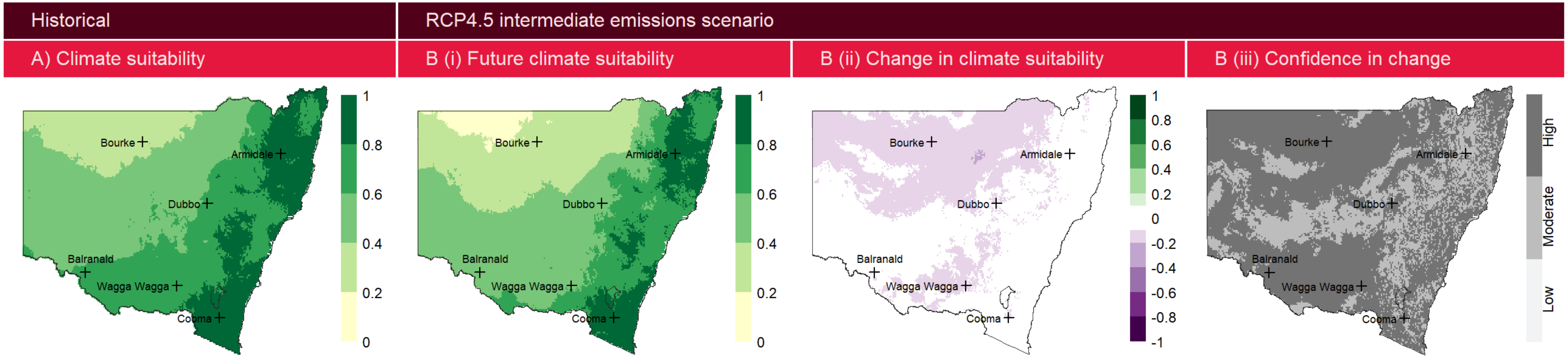


Figure 10: Overall climate suitability for sheep with winter lambing in NSW. This figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected future change in climate suitability as negligible (white), positive (green) or negative (purple) change, and iii) shows the level of model confidence associated with this change (low, moderate or high). Sites indicating key regions where sheep are grazed are marked by black crosses.

Sheep – Winter Lambing – Pre-Joining (Number of Days > Tmax of 35°C)



Findings: There is likely to be minimal negative change in climate suitability across much of the state *(moderate to high confidence),* with areas of moderate change in the north-east of the state *(high confidence)* under the high emissions scenario. These changes are due to an increase in the number of days of heat stress during this time of the year.

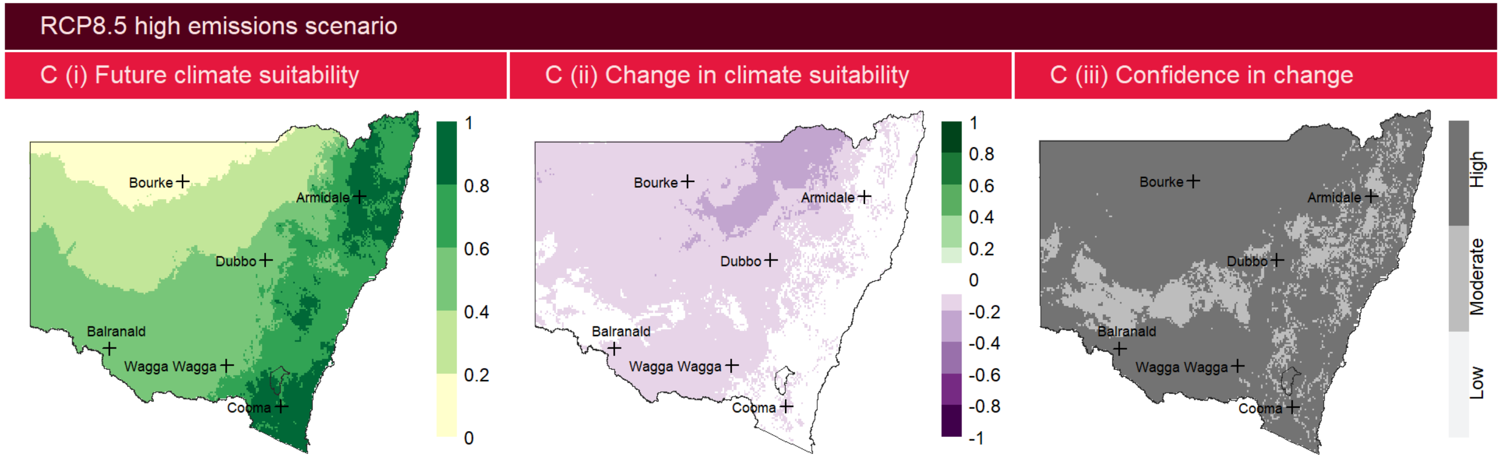
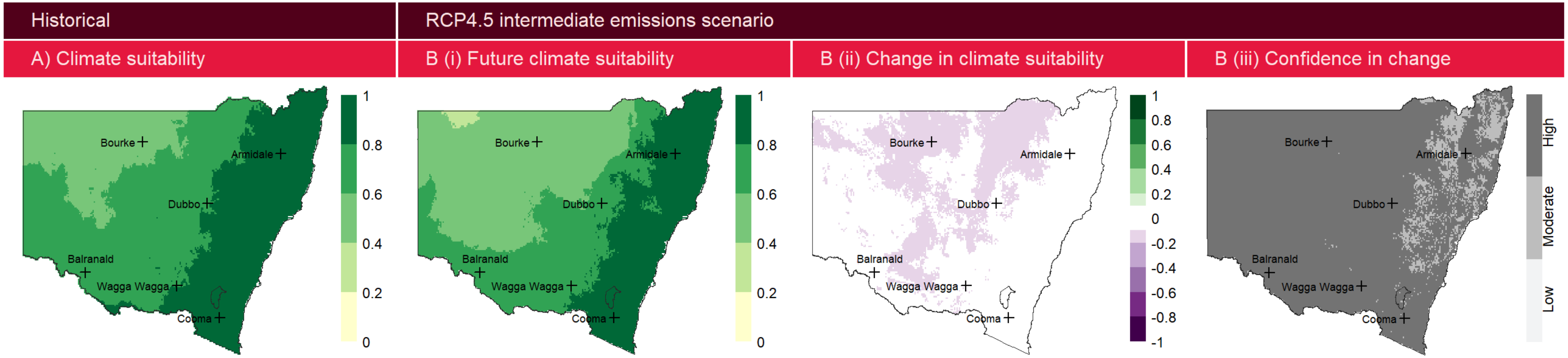


Figure 11: Climate suitability during pre-joining for sheep with winter lambing in NSW. This figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected future change in climate suitability as negligible (white), positive (green) or negative (purple) change, and iii) shows the level of model confidence associated with this change (low, moderate or high). Sites indicating key regions where sheep are grazed are marked by black crosses.

Sheep – Winter Lambing – 1st Trimester (Number of Days > Tmax of 35°C)



Findings: There is likely to be minimal negative change in climate suitability across much of the state *(moderate to high confidence)*, with areas of moderate change in the north east of the state (*high confidence)* under the high emissions scenario. These changes are due to an increase in the number of days of heat stress during this time of the year.

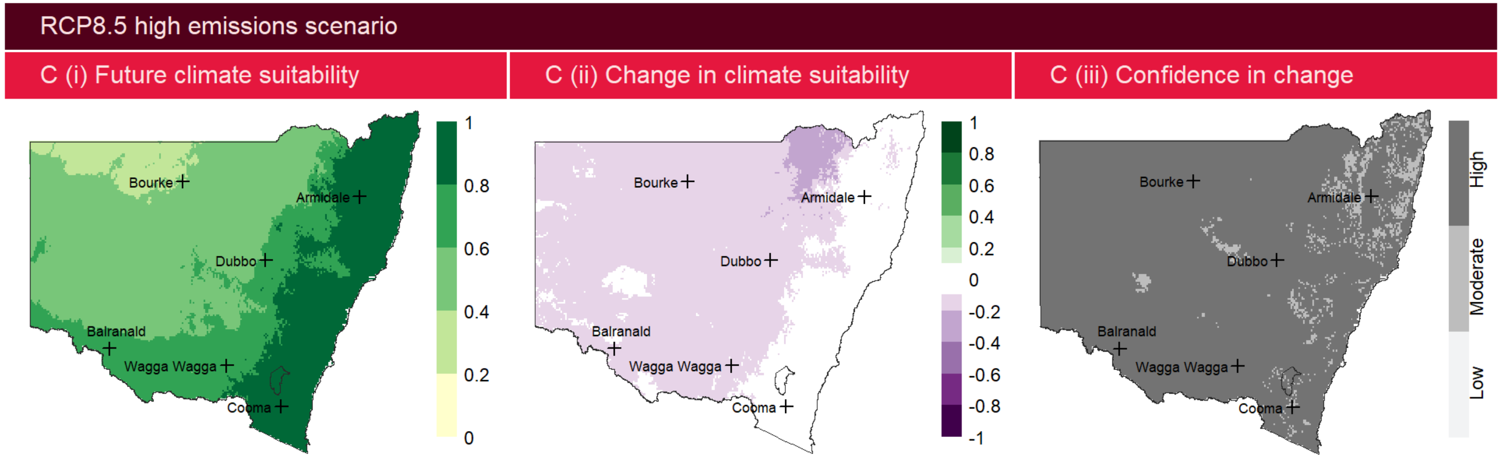


Figure 12: Climate suitability during the first trimester for sheep with winter lambing in NSW. This figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected future change in climate suitability as negligible (white), positive (green) or negative (purple) change, and iii) shows the level of model confidence associated with this change (low, moderate or high). Sites indicating key regions where sheep are grazed are marked by black crosses.

Key findings and insights from a changing climate

The results of this study provide valuable insights into the historical and potential future climate suitability of sheep, with implications for livestock producers.

Historical and future trends

Climate change is likely to challenge some aspects of sheep production in NSW, with some areas expected to experience decreases in climate suitability for winter lambing whilst spring lambing overall is expected to maintain its high to very high climate suitability.

Future climate vulnerabilities

Spring lambing: There is likely to be a minimal to moderate decrease in climate suitability across northern and central NSW due to the increase in days greater than 35°C during pre-joining (*moderate to high confidence*). This is likely to impact sheep reproduction efficiency in the future. In a high emissions scenario, this minimal decrease extends across most of the state west of the Great Dividing Range (*moderate to high confidence*).

Winter lambing: There is likely to be a minimal to moderate decrease in climate suitability across northern and western NSW due to the increase in days greater than 35°C during pre-joining (*moderate to high confidence*). This is likely to impact sheep reproduction efficiency in the future. There is also likely to be a minimal decrease in suitability in central and northern NSW due to an increase in the number of days which have a minimum temperature greater than 25°C (*moderate to high confidence*).

Future climate opportunities

There is likely to be a reduction in the chill index (see call-out box, page 10) during the lambing period for the spring lambing production system in the Armidale region (*high confidence*). This may increase the number of lambs surviving the neonatal period to weaning.

Sheep climate suitability in survivability and feed intake will remain similar to what has been historically experienced (*moderate to high confidence*).

Adapting to the changing climate

Assessing future climate suitability is a prerequisite to making effective decisions around planning for livestock enterprises and developing effective adaptation strategies for addressing future climate change.

Sheep producers could investigate strategies such as:

- Management changes, such as moving the joining time to a cooler period, to mitigate heat exposure of sheep and lambs.
- Managing heat stress through actions such as providing shade, ensuring access to water to avoid dehydration, adjusting supplementary feeding times to cooler parts of the day, and limiting sheep movement can all help. Proactive planning and implementation of these actions are crucial for minimising impacts on livestock. To assist with this, you can use a forecast tool to help plan ahead.
- Consideration should also be given to adjusting shearing schedules to manage heat stress. Sheep are better protected from heat when their wool is about 40mm long. If their wool is shorter than this, the sun’s heat more easily reaches their skin, making them more susceptible to heat stress.

Tools for informed management

Forecasts for heatwaves: The Bureau of Meteorology's forecasts predict heatwaves up to seven days in advance. Warnings for severe or extreme heatwaves are issued four days ahead of time. These warnings include detailed information on expected temperatures and the areas that will be affected.

You can access the heatwave warnings through the BOM weather app or at

http://www.bom.gov.au/australia/heatwave/knowledge-centre/heatwave-service.shtml

Grazing systems snapshot: what are the projected changes for NSW?

Within NSW, several different grazing systems are used for extensive livestock production. Climate vulnerability assessments have been conducted for three key grazing systems in NSW, and these should be considered alongside the sheep climate vulnerability assessment. The full reports for the grazing systems models are available on the website, but a snapshot of the key findings is included below.

Rangeland zone grazing system | Low stocking rate

Rangeland grazing systems in all seasons are likely to retain their historical ability to meet animal feed requirements by 2050 (moderate *confidence*). However, a small region along the north-western boundary of the Western Division may slightly decline in climate suitability from very high to high suitability (*moderate confidence*).

Mixed cropping zone grazing system | Moderate stocking rate

Autumn is likely to have a minimal to moderate decrease in climate suitability across mixed cropping zone grazing systems under both emissions scenarios (*moderate to high confidence*). This is driven by increased temperatures and more variable rainfall.

Winter's ability to meet animal feed requirements will likely remain similar to what has been historically experienced in the mixed cropping zone grazing systems (*moderate confidence*)

Spring's ability to meet animal feed requirements is expected to have a minimal to moderate decrease in suitability by 2050 in the western parts of the mixed cropping zone (*moderate to high confidence*).

Summer is likely to have a widespread minimal decrease in the ability to meet animal feed requirements across the mixed cropping zone under a high emissions scenario (*moderate confidence*).

High rainfall zone grazing system | High stocking rate

Autumn is likely to experience a minimal to moderate decrease in sown pastures' ability to meet animal feed requirements (*moderate to high confidence*). This is expected to be driven by increased temperatures and more variable rainfall. Native pastures are likely to maintain similar suitability to what has been historically experienced (*moderate to high confidence*).

Winter's ability to meet animal feed requirements is likely to remain similar to historical levels in high rainfall zone grazing systems (*moderate confidence*).

Spring's ability to meet animal feed requirements is likely to remain similar to historical levels in high rainfall zone grazing systems (*moderate confidence*).

Summer is likely to see a minimal to moderate decrease in the ability to meet animal feed requirements using sown pastures under both emission scenarios due to increased temperatures and more variable rainfall (*moderate to high confidence*). Native pastures are likely to provide a similar ability to meet animal feed requirements to historical levels (*moderate confidence*)**.**

Sheep: where to from here?

Future priorities

The results presented in this report have identified changes in climate suitability for sheep that will likely impact the industry in NSW. More research and development is needed to best advise the industry on managing sheep, looking forward to 2050.

The next stage of work would be to conduct a detailed assessment of adaptation strategies to provide industry with insights into the value of adaptation for reducing the impacts of climate change. Effective management approaches must be carefully planned, evaluated, and deployed to minimise disruptions and costs. The following options may merit initial consideration:

- Adapting to increased heat stress by changing the timing of the joining and managing the consequences of this change to avoid times of year when there is a heightened risk of heat stress that impacts reproductive performance.
- Investigating the usefulness and effectiveness of forecasting tools in helping farmers adopt proactive approaches to heat stress management. Targeted use of these tools could help to minimise impacts on sheep and maximise the effectiveness of any strategies deployed.

Addressing the gaps, barriers and challenges

The new information generated by this project has helped identify the climate vulnerabilities for sheep. However, many knowledge gaps were identified during the development of the MCA model.

In some cases, these knowledge gaps were barriers to developing the models. In some instances, they led to the exclusion of key climate criteria because there was a lack of data to justify their inclusion in the model. Based on experience in the MCA model development process, the following areas are deemed key knowledge gaps in need of further research:

- Impact of temperature on sheep reproduction.
- Impact of heat stress on rams and ewes pre-joining and gestation.
- Impact of heat stress on lamb feed intake and mortality.

This report highlights these gaps to assist in directing future research and project development. Consideration should be given to modelling other significant or emerging livestock breeds, pasture systems, and intensive livestock industries like dairy, poultry, and pigs, as well as expanding the range of the current modelling Australia-wide to inform future industry planning.

Conclusion

This work provides important baseline information to support state, regional and strategic industry-level planning for climate change, highlighting where adaptation and investment should be prioritised to sustain and enhance livestock industries and limit climate change's impacts on sheep.

The results presented in this report provide a comprehensive assessment of how climate suitability is likely to shift under climate change for this key commodity in NSW. This research also sets out the challenges ahead, which will require investment in adaptation strategies and education to underpin the livestock industry's future growth and sustainability.

NSW DPIRD will use these findings in partnership with industry to prioritise future efforts, strategic partnerships, and networks across the state to support effective policies and programs that keep primary industries resilient and productive in a changing climate.

For more information

For detailed information on the methodology and data used in this project please see the Climate Vulnerability Assessment Methodology Report.

Several climate vulnerability assessments have also been conducted for biosecurity risks including weeds and livestock parasites. The full reports for these biosecurity risks, alongside other commodities, can be found in the Climate Vulnerability Assessment Summary Report or on the project's website.

Other Climate Vulnerability Assessments that may be of particular interest are:

- Mixed cropping zone grazing systems
- High rainfall zone grazing systems
- Rangelands grazing systems

An accompanying report on NSW Drought in a Changing Climate provides a comprehensive understanding of how drought frequency and duration will change as a result of climate change and it is recommended to read this report alongside the results presented for sheep.

Contact us

For further information, please get in touch with vulnerability.assessment@dpird.nsw.gov.au

Acknowledgements

We thank the five experts who participated in the sheep focus groups. These experts ensured that the model contents reflected published knowledge and lived experiences and determined the relative influence or importance of different climate variables in the model.

Thanks to all the NSW Department of Primary Industries and Regional Development staff who participated in the NSW DPIRD Extensive Livestock Team: Forough Ataollahi, Gordon Refshauge, Mark Norton, Robin Dobos, Sarah McDonald, Todd Andrews, Trudie Atkinson and Warwick Badgery.

We thank the Climate Vulnerability Assessment team for driving this project from inception to completion over the last five years, individually acknowledging each team member: Joanna Pardoe, Rebecca Darbyshire, Gary Allan, Mary Timms, James Lawson, Lachlan Philips, Bethany Ellis, Jane Kelley, Samantha Currie, Rachael Young, Paris Capell, David Allingham and Chris Nunn.

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