Department of Primary Industries
and Regional Development

Cattle
Bos taurus

Results Report

Climate Vulnerability Assessment

NSW
GOVERNMENT

Authors

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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.

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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 cattle study within the Climate Vulnerability Assessment. It introduces the cattle industry in NSW and provides an overview of the 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.

Cattle in NSW

There are approximately 4.4 million head of beef cattle throughout NSW (Figure 1), which is about 18% of the Australian beef cattle population[5]. Beef cattle are found across NSW, covering a range of climatic environments, including subtropical, temperate and Mediterranean. These climates have a significant impact on the pasture base, pest and disease prevalence and influence breed selection and production systems.

The Australian beef-cattle industry was founded on *Bos taurus* cattle of British origin, particularly the Hereford, Shorthorn and Angus breeds. *Bos taurus* cattle are adapted to cooler climates and remain dominant in southern Australia.

As the *Bos taurus* breed is the dominant beef breed across NSW, the Climate Vulnerability Assessment is designed based on this breed.

Cattle production phases

Reproduction, survivability, feed intake/production and lactation were chosen as they key drivers of production performance in a cattle enterprise that could be affected by changing climate conditions, such as heat stress.

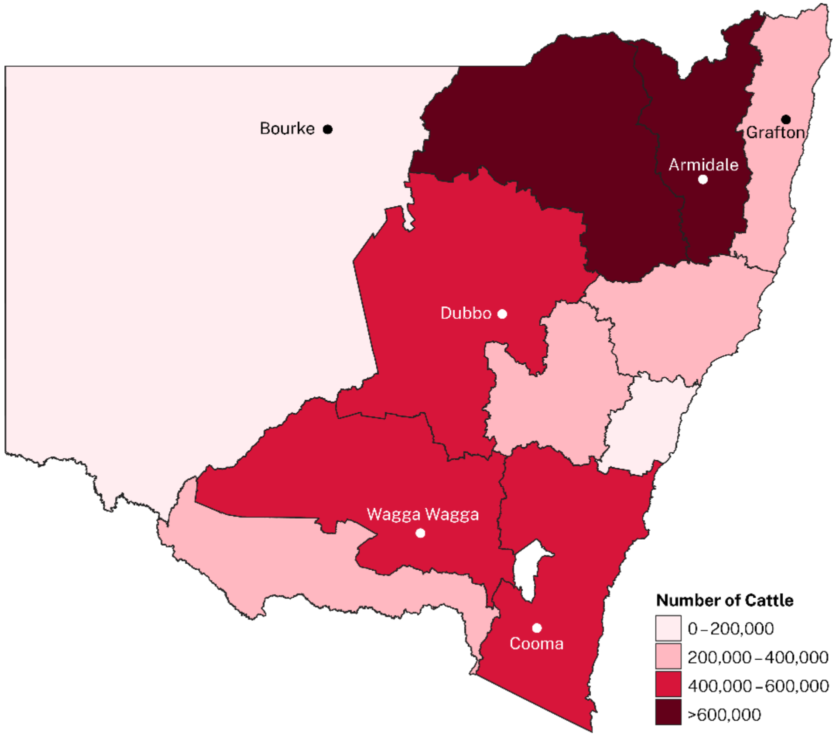


Figure 1. Cattle populations for different Local Land Service areas in NSW (ABS, 2021)

[5] Meat and Livestock Australia, 2021-2022

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 commodity 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 and reflect a consensus reached by the focus group experts.

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[6], 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 cattle 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 cattle and key results, showing important changes to future climate suitability for cattle.

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 cattle 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 cattle 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 non-climatic biophysical parameters
- socio-economic factors

These exclusions 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.

[6] 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 cattle 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 this model were maximum temperature (Tmax, °C) and the derived temperature-humidity index (THI).

Categorising climate variables

The hierarchical structure of the MCA model (Figure 3) categorises climate variables to assess their impact on cattle. 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 cattle, from unfavourable (R=0) to optimal (R=1). This is repeated for each production phase.

Modules used in the cattle MCA model

The cattle 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 cattle.

What is THI?

Temperature humidity index (THI) measures the perceived temperature based on air temperature and relative humidity. It is a way to measure how hot it feels when humidity is factored in with the actual air temperature.

The THI values indicate the level of heat stress the livestock are experiencing. The higher the THI value, the more heat stress the animal is feeling and the greater the production losses. For the THI calculation used in this assessment, please see the Climate Vulnerability Assessment Methodology Report.

Cattle model assumptions

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

- the model is focused on *Bos taurus* as this is the main breed in NSW
- best practice management is undertaken.
- the livestock and pastures are free of pests and diseases.
- adequate feed and water are available.
- specific joining and calving dates were selected and are not necessarily appropriate for all livestock operations in NSW.
- dates of production phases are fixed.

Cattle model overview

The cattle MCA model contains 4 phenophases, 'reproduction', 'survivability', 'production' and 'lactation'. The model has been run with calving dates from mid-July to the end of October, representing an average between the southern (generally earlier calving) and northern systems (generally later calving). The full set of dates used for the MCA model are indicated in Table 1.

'Reproduction' is the highest weighted of phenophase, representing 60% of the overall model, followed by ‘production’ (29% of the model). The phenophases are broken down into sub-phenophases, and these are primarily dependent on THI (a heat stress index, see call-out box on page 7). THI values below 72 to 75 are ideal across the model, with the climate suitability dropping above these values. The ‘pre-joining’ sub-phenophase, under ‘reproduction’, depends also on the number of days with maximum temperature above 36°C (fewer than 3 days is ideal).

Table 1: Production phase dates used in the cattle MCA model for NSW enterprises

Production Phase	Dates
Pre-Joining	25 Aug – 30 Sep
Joining	1 Oct – 15 Dec
Gestation	1 Oct – 31 Dec
Calving	15 Jul – 31 Oct
Cow Feed Intake	Year Round
Calf Feed Intake	15 Feb – 1 May
Lactation	15 Aug – 31 Dec

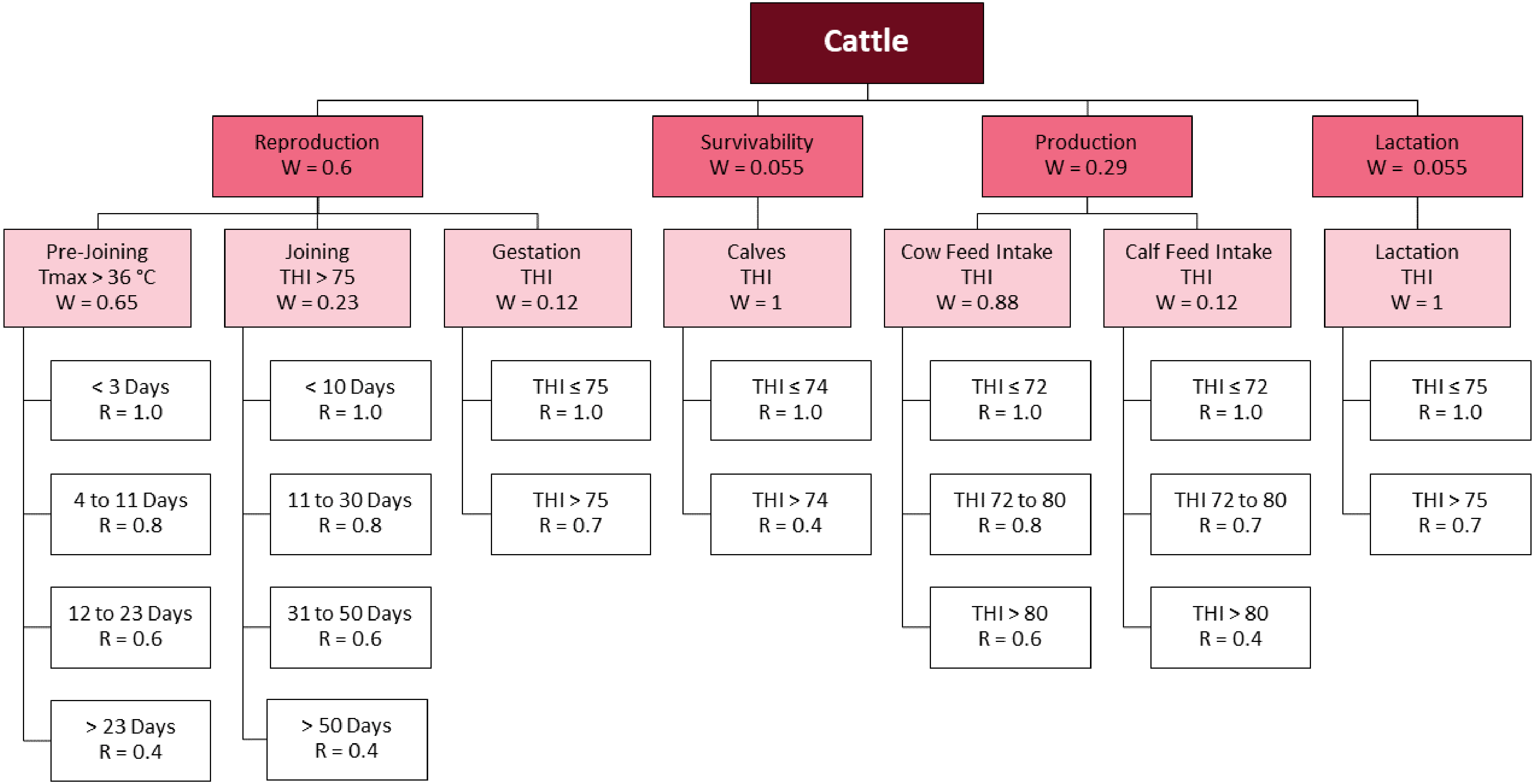


Figure 3: Hierarchical structure and model components of the cattle MCA Model. The top-level of the hierarchy is the commodity. The second level contains the production phases identified as climate-sensitive by the literature review and expert judgment. The third level contains climate variables which 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 cattle regions are displayed on each map to indicate the areas where cattle 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[7], and the median of these models was used to produce ensemble future projection climate suitability maps.

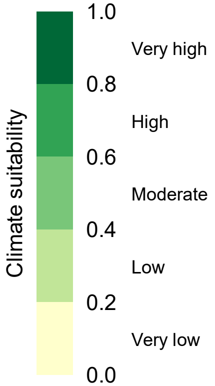


Figure 4: Colour scheme for the climate suitability maps

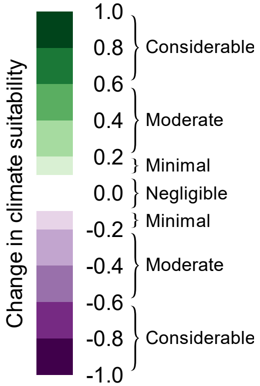


Figure 5: Colour scheme for the change in climate suitability maps

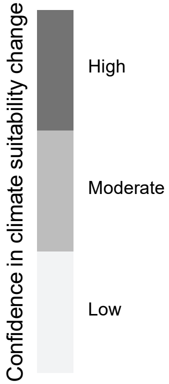


Figure 6: Colour scheme for the confidence in the change in climate suitability maps

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.

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

Understanding climate suitability: a guide to map interpretation

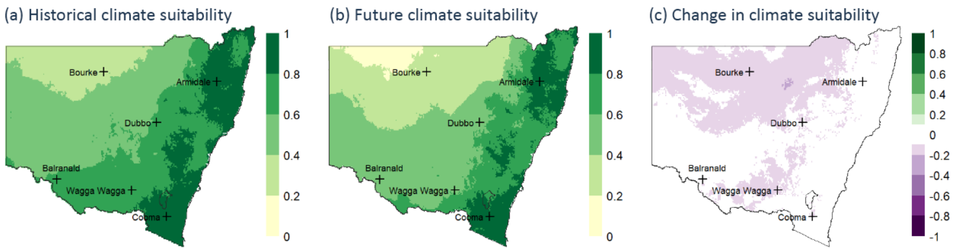
The Climate Vulnerability Assessment has strived for accuracy and clear interpretation in our data representation, particularly when there is uncertainty. The MCA models produce continuous climate suitability values. To help readers interpret the maps, these suitability values have been grouped into 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.

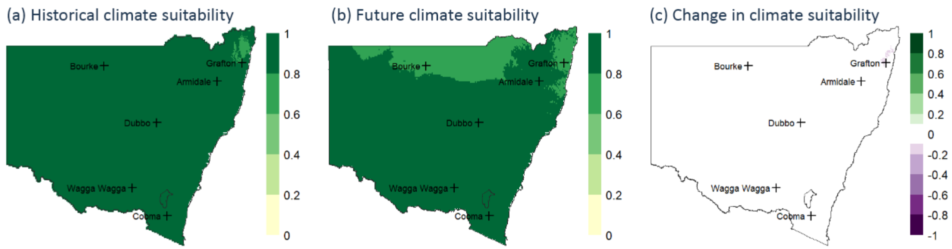
Why does the 'change in climate suitability' map show changes in some places where the historical and future climate suitability maps have the same colour? There are instances where historical and future climate suitability maps show the same category of climate suitability, yet the change in suitability 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 cattle

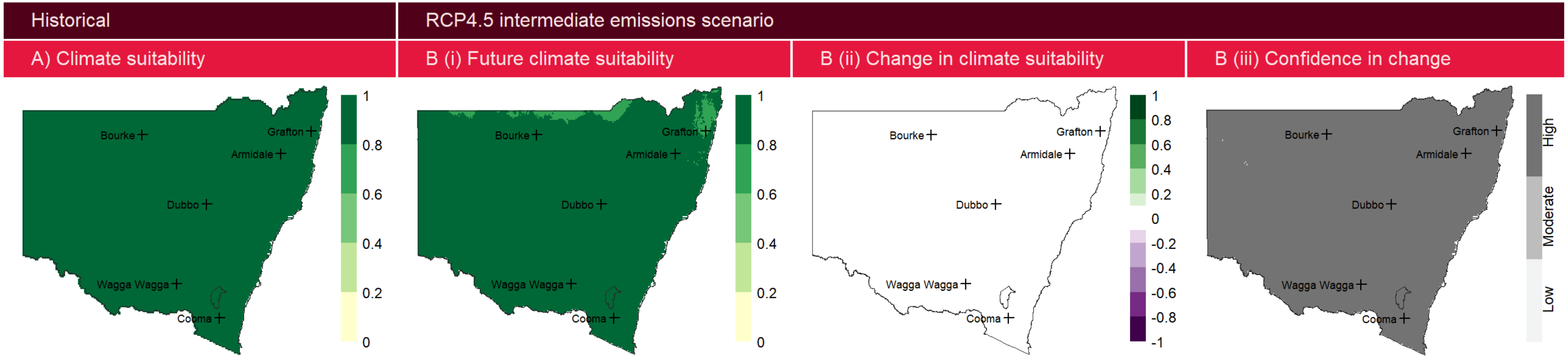
Climate change is likely to offer both opportunities and challenges for cattle production in NSW by 2050.

This section provides a selection of key results for the cattle model. The section begins with an overview of the main impacts, vulnerabilities, and opportunities, followed by key maps from the assessment 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

Overall cattle climate suitability (Figure 7) is likely to maintain high to very high climate suitability across NSW for both emissions scenarios by 2050 (*high confidence*). As climate suitability is likely to remain similar to what has been historically experienced, current production strategies are likely to remain effective for producers across the entire state.

Cattle – Overall



Findings: Climate suitability is likely to remain similar to what has been historically experienced across the entire state (*high confidence*). Current production strategies are likely to remain effective.

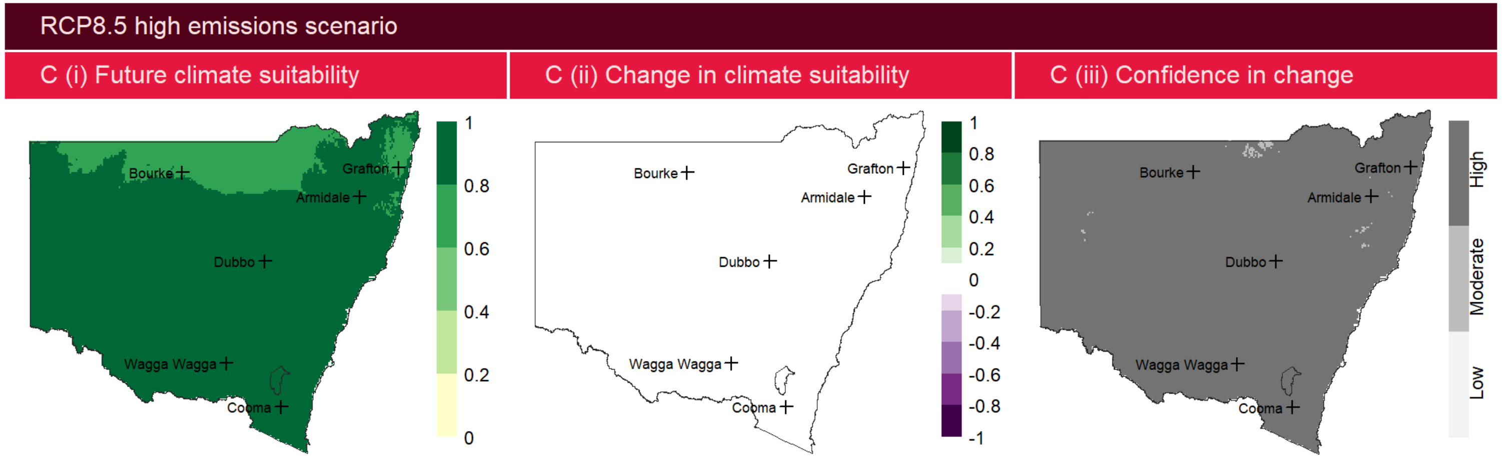


Figure 7: Overall climate suitability for cattle production in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected 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 cattle are grazed are marked by black crosses.

Climate impacts on production phases

Climate change impacts on the NSW cattle industry are likely to affect the production phases of the cattle industry in different ways:

- During the **reproduction phase**, joining (Figure 8) is likely to experience a minimal decrease to moderate climate suitability across most of NSW under both scenarios (*high confidence*) due to an increase in the number of days of heat stress during this time of the year. Gestation and pre-joining are both expected to retain high to very high suitability across NSW in both emissions scenarios.
- **Survivability of calves** overall is expected to retain similar climate suitability to what has been experienced historically (Figure 9). In a high emissions scenario, north-east NSW may minimally decrease in climate suitability due to increased heat stress (*high confidence*).
- **Calf feed intake** (Figure 10) is likely to experience a minimal decrease in climate suitability in northeast NSW under high emissions scenario (*high confidence*). The decrease in suitability for feed intake of calves is likely is due to expected increased temperatures under future climate conditions. Cow feed intake expected to retain similar climate suitability to what has been experienced historically.
- **Lactation** (Figure 11) is expected to remain very highly suitable across NSW in both emissions scenarios (*high confidence*).

Feed intake requirements

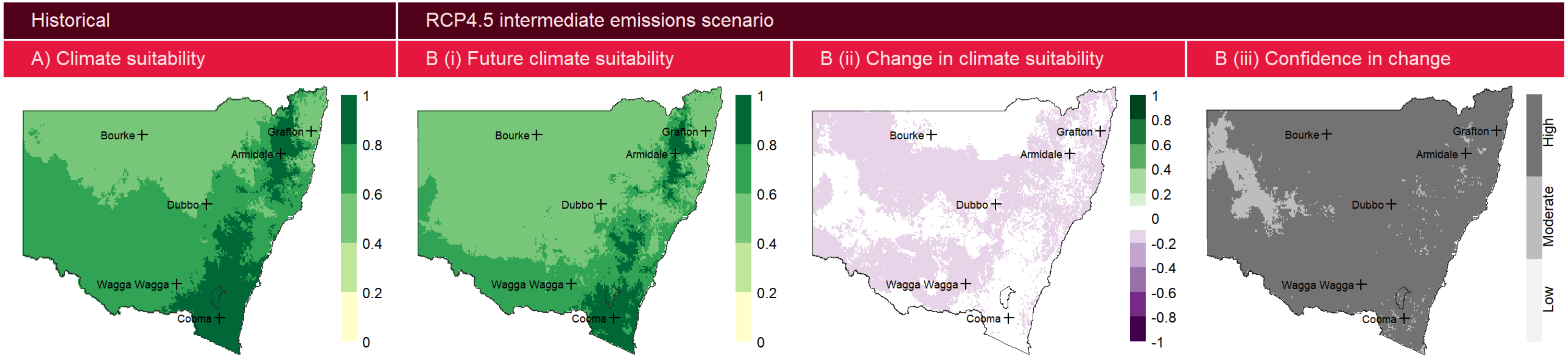
Feed intake requirements refer to the amount and type of feed needed to meet the nutritional requirements of animals.

What is THI?

Temperature humidity index (THI) measures the perceived temperature based on air temperature and relative humidity. It is a way to measure how hot it feels when humidity is factored in with the actual air temperature.

The THI values indicate the level of heat stress the livestock are experiencing. The higher the THI value, the more heat stress the animal is feeling and the greater the production losses. For the THI calculation used in this assessment, please see the Climate Vulnerability Assessment Methodology Report.

Cattle – Heat stress at joining



Findings: There is likely to be minimal negative change in climate suitability across most of the state *(moderate to high confidence)* due to an increase in the number of days of heat stress during this time of the year. These impacts are likely to be exaggerated if producers join 1-2 months later than the model-defined period of early October to mid-December.

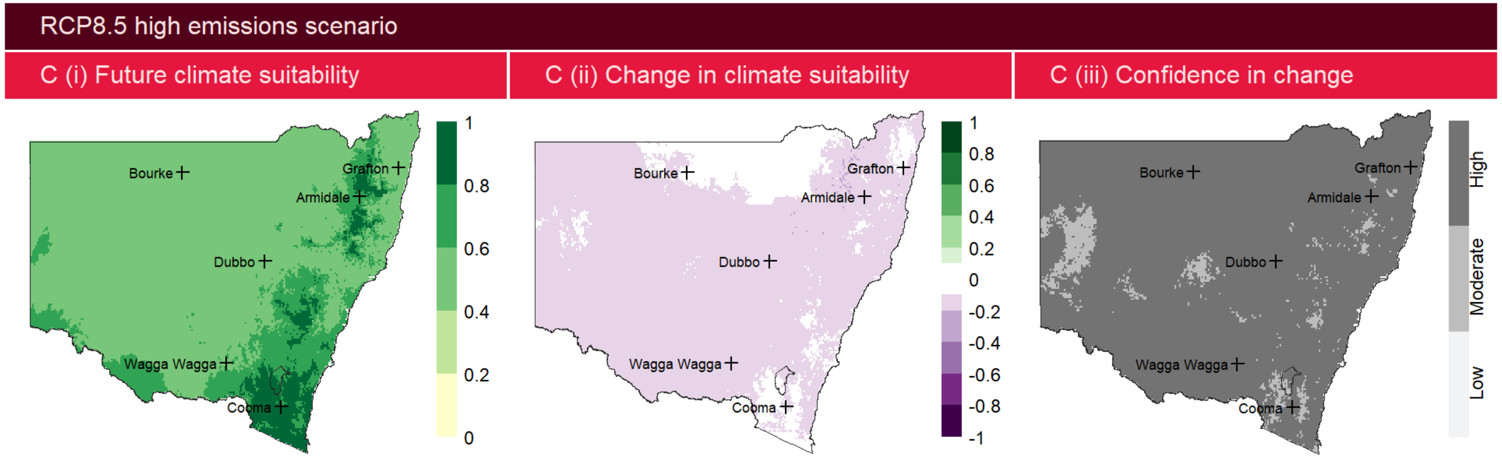
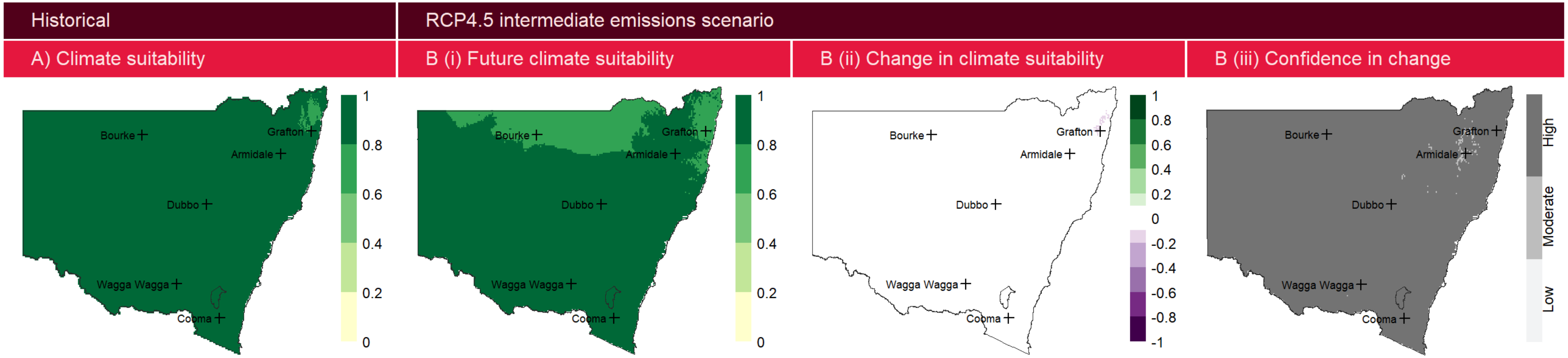


Figure 8: Overall climate suitability for cattle production in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected 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 cattle are grazed are marked by black crosses.

Cattle – Survivability of calves



Findings: Most of the state is likely to maintain similar climate suitability to what has been historically experienced. In a high emissions scenario, north-east NSW may minimally decrease in climate suitability due to increased heat stress (*high confidence*).

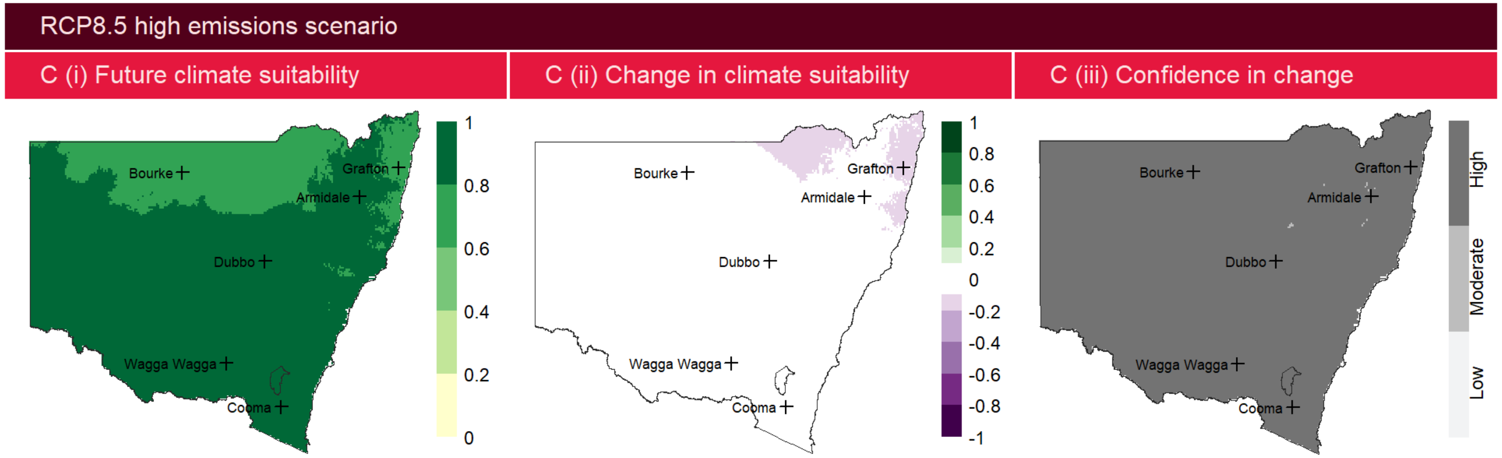
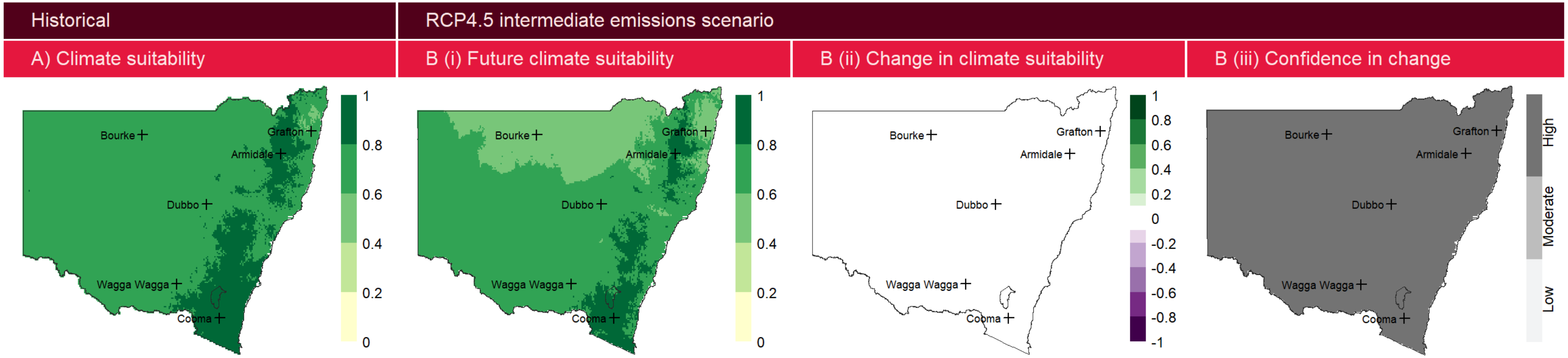


Figure 9: Climate suitability for survivability of calves in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected 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 cattle are grazed are marked by black crosses.

Cattle – Feed intake for calves



Findings: Most of the state is likely to experience similar climate suitability to what has been historically experienced (*high confidence*), except for the north east of the state under the high emissions scenario where there is minimal negative change in climate suitability (*high confidence*). Feed intake of calves may decrease due to this increase in heat stress.

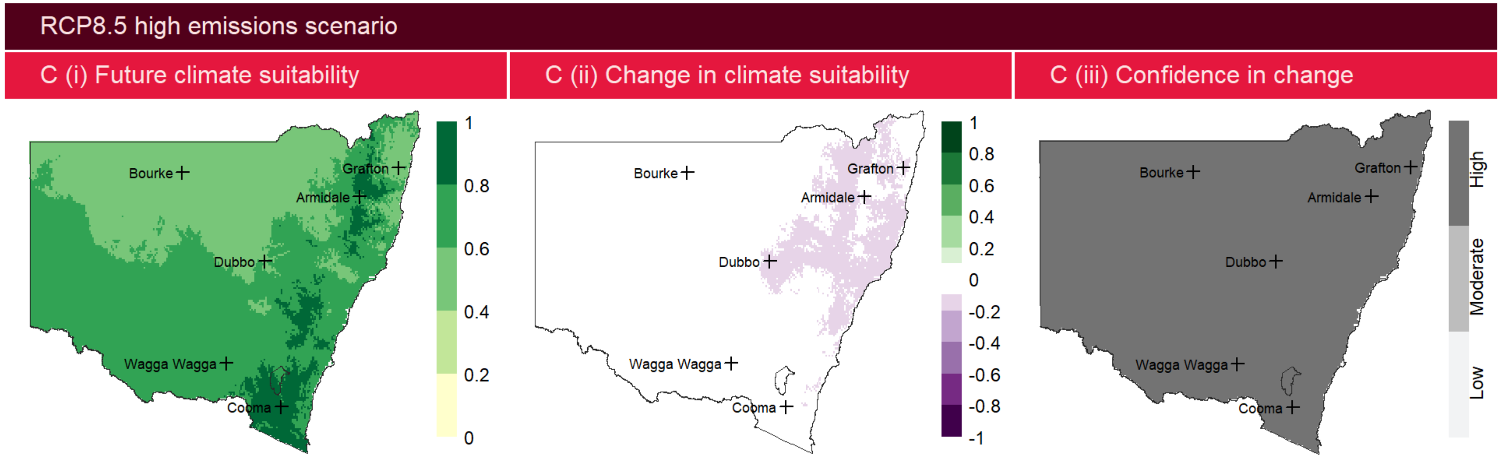
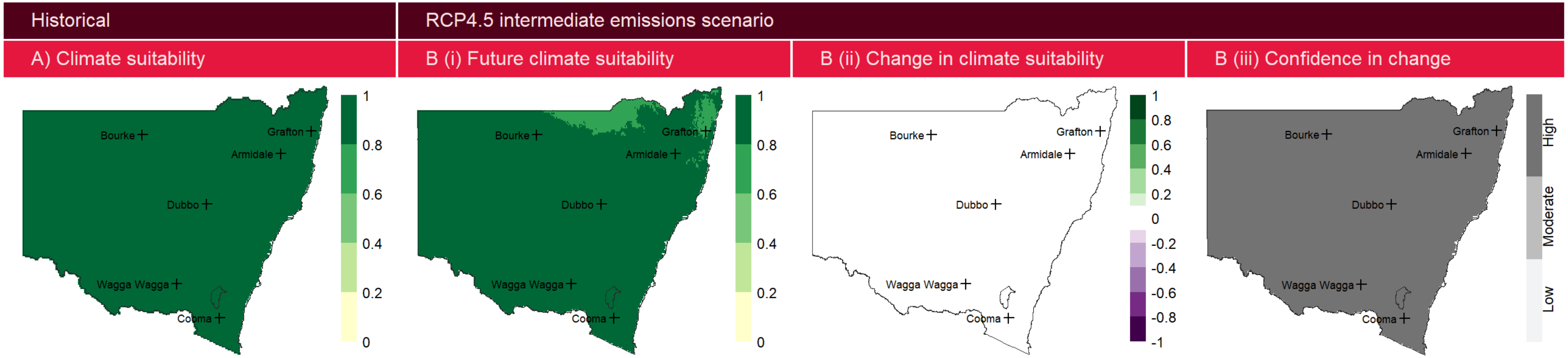


Figure 10: Overall climate suitability for calf feed intake in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected 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 cattle are grazed are marked by black crosses.

Cattle – Lactation



Findings: Climate suitability is expected to remain high to very highly suitable across NSW in both emissions scenarios (*high confidence*).

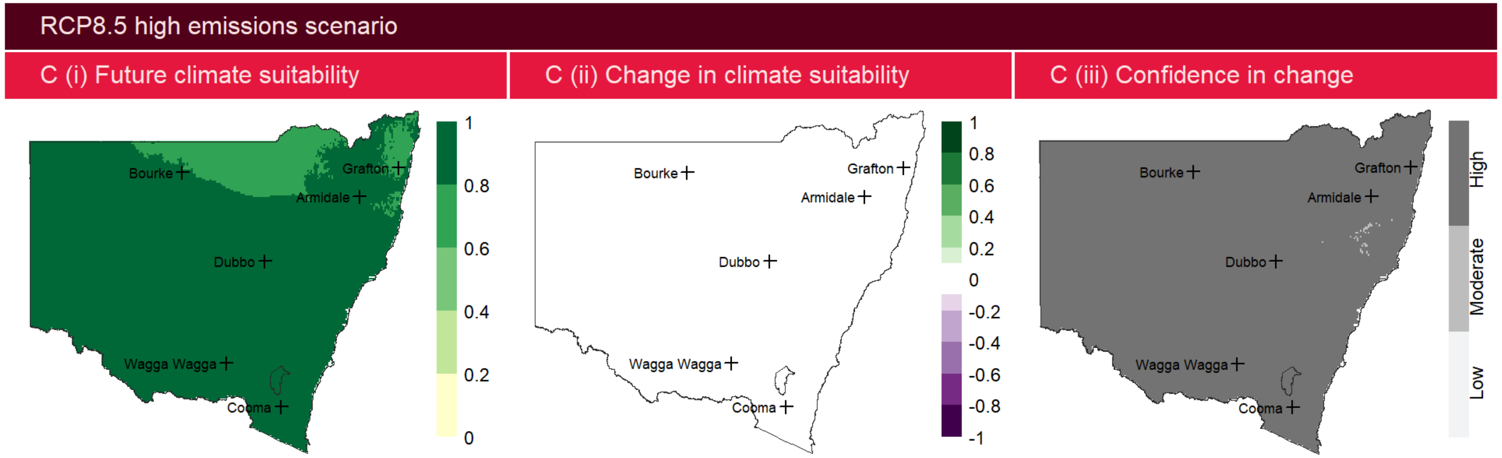


Figure 11: Climate suitability for cattle lactation in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected 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 cattle 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 cattle, with implications for livestock producers.

Historical and future trends

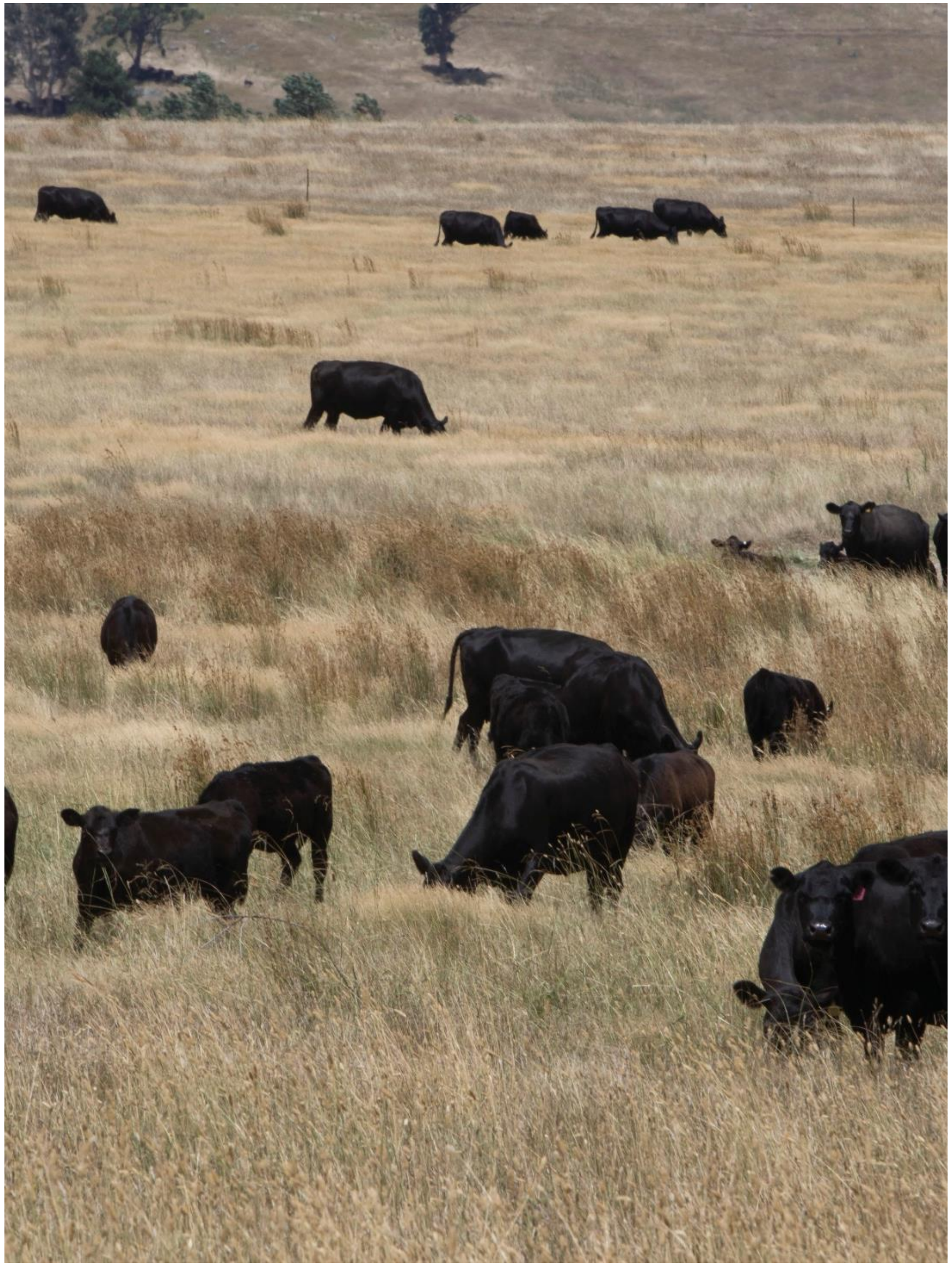
Overall cattle climate suitability is likely to maintain high to very high climate suitability across NSW for both emissions scenarios in 2050 (*high confidence*).

Future climate vulnerabilities

Joining and calf feed intake are likely to experience a minimal reduction in climate suitability (*high confidence*) due to higher temperatures and humidity. In NSW's central and western regions, where minor negative changes are expected, these impacts are likely to be exaggerated if producers join 1-2 months later (during January and February) than the model-defined period of early October to mid-December.

Future climate opportunities

Climate suitability during survivability for calves and lactation are likely to remain very highly suitable (*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. Cattle producers could investigate strategies such as:

- Bringing joining forward is a potential adaptation for reducing heat stress during calving. Dates will depend on the region, but calving in late spring instead of early summer could mitigate heat exposure of cows and calves. However, adjusting calving timing is sometimes not possible or is complicated by a lack of oestrus in cows due to low body weight or fat scores.
- Weaning calves earlier in warmer years to maintain cow body weight is a demonstrated management option.
- 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 cattle movement can 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.

Tools for informed management

Forecasts for Heat Stress: Understanding the forecast heat stress (THI, temperature humidity index) for your region is now easier than ever with a new, freely-available tool. This resource allows you to see forecast heat stress and make informed management decisions, helping you mitigate heat stress's effects on your cattle.

You can access the thermal stress forecasts at https://nacp.org.au/cattle_thermal_stress_forecasts

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 cattle 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 current abilities 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 what has been historically experienced in high rainfall zone grazing systems (*moderate confidence*)

Spring's ability to meet animal feed requirements is likely to remain similar to what has been historically experienced in high rainfall zone grazing systems (*moderate confidence*).

Summer is likely to have a minimal to moderate decrease in sown pastures ability to meet animal feed requirements under both emission scenarios due to increased temperatures and more variable rainfall (*moderate to high confidence*). Native pastures are likely to maintain similar suitability to what has been historically experienced (*moderate confidence*)

Buffalo fly snapshot: what are the projected changes for NSW?

Parasites significantly impact livestock health and productivity. Both internal parasites, such as worms, and external parasites, such as ticks and flies, pose serious threats. They can reduce the productivity and health of grazing animals, leading to lower weight gains. Some parasites can also cause skin irritations and transmit disease, further impacting livestock health.

The external life stages of parasites are influenced by climate conditions that can change their development and survival rates. Several climate vulnerability assessments have also been completed for livestock parasites and these should be considered alongside the cattle climate vulnerability assessment.

Buffalo fly | *Haematobia irritans exigua*

Changes in buffalo fly climate suitability are likely to create challenges for the beef industry. By 2050, climate change will increase the climate suitability for all life stages of the buffalo fly in northeastern NSW during spring and autumn, especially under a high emissions scenario. Summer is likely to continue to be highly suitable for the flies in this region.

Impact on extensive livestock

The increased climate suitability for buffalo fly in spring and autumn is likely to support the flies spreading further south and west into inland NSW. This could lead to significant impacts on the beef industry in these previously unaffected areas. *Bos taurus* breeds in southern NSW are more susceptible to buffalo fly than *Bos indicus* breeds in warmer climates.

Management practices used in the current endemic region for buffalo fly in far-northeast NSW will also likely be effective in southern and inland regions. Industry and government will need to support these regions through education programs advising on the likely increasing southward and inland spread of buffalo fly under a warmer future by 2050 and supporting the deployment of management strategies.

For more information

Further modelling of livestock parasites including cattle tick, *Culicoides brevitarsis*, barbers pole worm and sheep blowfly, is currently underway and will be available on the website in 2025.

The full reports for buffalo fly and other biosecurity risks can be found in the Climate Vulnerability Assessment Summary Report or on the website.

Cattle: where to from here?

Future priorities

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

The next stage of work is to conduct a detailed assessment of adaptation strategies to provide industries 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:

- Breeding programs to select cattle with improved tolerance to hot and humid conditions,
- Assessing the effectiveness of adjusting calving times to avoid weather where heat stress is more likely to occur,
- 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 cattle 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 cattle. 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. The following areas are deemed key knowledge gaps in need of further research:

- Impacts of heat stress on *Bos taurus* reproduction
- Impacts of heat stress on feed intake
- Impacts of heat stress on calf survivability

While THI limits are well understood, there are several different published methods of calculating THI. Each of these produces slightly different results. The lack of standardisation is an inherent challenge for livestock industries in preparing for future management of THI risk.

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 cattle.

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.

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.

Results from other commodities and biosecurity risk assessments can be found in the Climate Vulnerability Assessment Summary Report or on the 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 cattle.

Contact us

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

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