Department of Primary Industries
and Regional Development

High Rainfall Zone Grazing Systems

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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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 High Rainfall Grazing Systems (referred throughout as 'HRZ') model within the Climate Vulnerability Assessment. It introduces the HRZ 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.

High Rainfall Zone Grazing Systems in NSW

High rainfall zone grazing systems (HRZ) cover a region across the Northern, Central and Southern Tablelands of NSW, where rainfall typically exceeds 600mm per annum on fertile soils. (Figure 1). High rainfall zones are characterised by a diverse range of pastures including sown grasses and annual legumes, and native grass pastures. Rather than analysing the growth stages of individual grasses and legumes, the ability of this pasture system to meet animal feed requirements was analysed for each season.

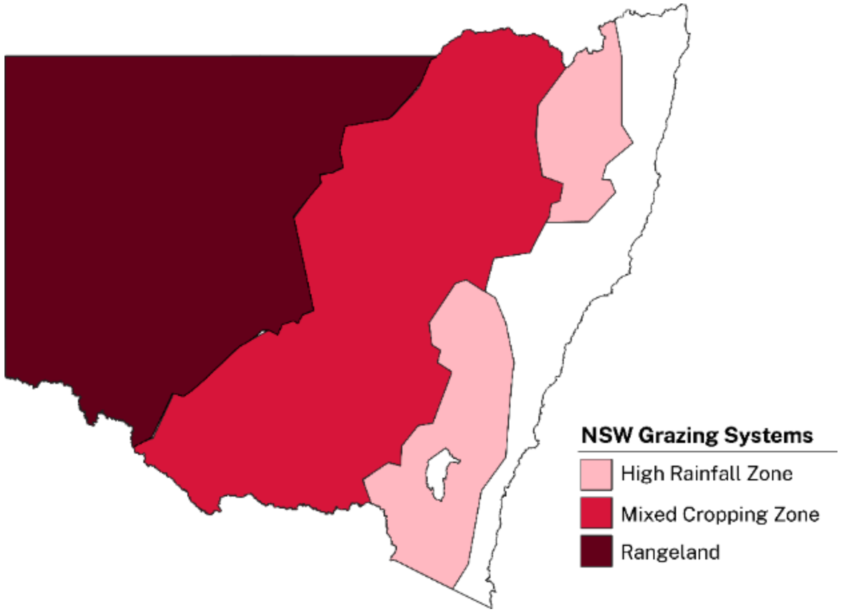


Figure 1: Map of NSW Grazing Systems used in the Climate Vulnerability Assessment

The ability for this pasture system to meet the feed intake requirements of livestock was analysed using a spring lambing/calving system, as this is common for livestock enterprises in the HRZ. The animal feed requirements change throughout the year depending on their physiological requirements and numbers. Generally, the energy requirements of animals are greatest through lambing/calving and lactation.

The HRZ was analysed using a spring lambing/calving system with a stocking rate of 19 DSE/ha for sown pastures and 10 DSE/ ha for native pastures, considered representative of livestock enterprises employing HRZ.

What is DSE?

Dry Sheep Equivalent (DSE) is a standardised unit used in grazing to measure the feed consumption of different animals. One DSE is equivalent to the feed intake required to maintain a 50kg wether. This allows producers to compare the grazing impact of different animals on pasture.

What is a stocking rate?

Stocking rate refers to the number of livestock on an area of lad over a specific period of time.

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. Internal and external experts are involved throughout the process, helping to develop and refine the model of their primary industry 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 , 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 HRZ 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 HRZ and key results, showing important changes to future climate suitability for HRZ.

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 HRZ 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 HRZ 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
- Soil properties
- 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.

Overview of the HRZ 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, mean temperature (Tmean, °C), evapotranspiration (ETO) and rainfall (Rain, mm).

Categorising climate variables

The hierarchical structure of the MCA model (Figure 3) categorises climate variables to assess their impact on HRZ. 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 HRZ grazing system, from unfavourable (R=0) to optimal (R=1).

Modules used in HRZ MCA model

The HRZ 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 period. Sometimes, extreme climate conditions that are fatal to pastures also need to be considered. If these limits are reached, the pasture dies, and the climate suitability is set to zero for that period in that year. Indicated by R = -2.
- **Matrix module**: Matrices capture the interaction between two climate variables. This module was used for stages that are particularly sensitive to the interplay between two climate variables. The matrix categories define different combinations of climate conditions, for example, temperature between 12 and 25°C with cumulative rainfall of between 48 and 170 mm. The matrix ratings for each climate variable combination indicate how well the pasture can meet animal intake needs under various conditions. This rating indicates whether the HRZ grazing system can meet the intake requirements of livestock (R=1) or cannot meet the intake requirements (R=0).

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 HRZ.

HRZ 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 project-wide assumptions and exclusions, the HRZ model also contains the following model specific assumptions:

- best practice management is undertaken.
- appropriate grazing management is employed.
- the pastures are free of pests and diseases.
- modelled for a winter lambing or calving system.
- Stocking rates were selected to be representative of the system. In this model, HRZ uses a 19 DSE/ha stocking rate for sown pastures and 10 DSE/ha for stocking rate for native pastures.

SGS model: How was it used to determine the ratings in the matrices?

The interaction of rainfall with temperature is a dominant driver of pasture growth and quality. A matrix approach was used to represent this interaction. The ratings for each combination of the climate variables reflect the ability of the pasture to meet animal intake requirements under different conditions that were determined by using the SGS-modelled pasture intake from 1901 to 2018 at 9 HRZ sites in NSW (Johnson *et al.* 2003). Temperature and rainfall categories were established using mean temperatures and rainfall sums for the 5th, 40th, 60th and 95th quantiles for the 9 sites.

For each temperature and rainfall category in each seasonal matrix, ratings were determined using the mean values of pasture intake divided by mean intake for the season, which provided a measure of the ability of the pasture to meet the animals' requirements. Some adjustments to the rating were made through focus groups' knowledge and understanding of the SGS model and HRZ grazing systems in NSW.

SGS Assumptions

- For the sown C3 and annual legume pasture, a phalaris and subterranean clover pasture system with 1000 ewes was modelled on a 100 ha property (19 DSE/ha).
- For the native pasture scenario, a native C3 generic grass pasture was modelled with 550 ewes on a 100-ha property (10 DSE/ha).
- Light to medium soil properties, medium organic matter, and nutrients.
- The ewe production calendar was aligned with the Merino MCA calendar (September lambing).
- The cattle system was presumed to yield similar annual demand patterns for the same stocking rate.

Johnson, IR, Lodge, GM, R.E., W (2003) The Sustainable Grazing Systems Pasture Model: Description, philosophy and application to the SGS National Experiment. *Australian Journal of Experimental Agriculture* **43**

Final HRZ Model

The final MCA model with weightings for HRZ is shown on the following page. The model has been divided into the two common pasture systems for HRZ grazing systems and the model weighted both the sown and native pasture systems of equal importance:

- sown pasture with grasses annual legumes typically support an annual stocking rate of 19DSE/ha;
- native grass pastures supporting an annual stocking rate of 10DSE/ha.

Rather than analysing the growth stages of individual pastures, the ability of each pasture type to meet animal feed requirements was analysed for each season. Seasonal time periods were used to represent changes in pasture growth patterns and changes in feed requirements over the livestock production cycle. The persistence of the sown pasture was also considered as there is a significant cost investment in establishing these pastures. This has been divided into persistence of perennial and annual species.

Some variables were modelled using matrices, which capture the interaction of the rainfall and temperature. The climate variables are categorised into ideal conditions and further categorised to capture conditions less than or greater than the optimal range.

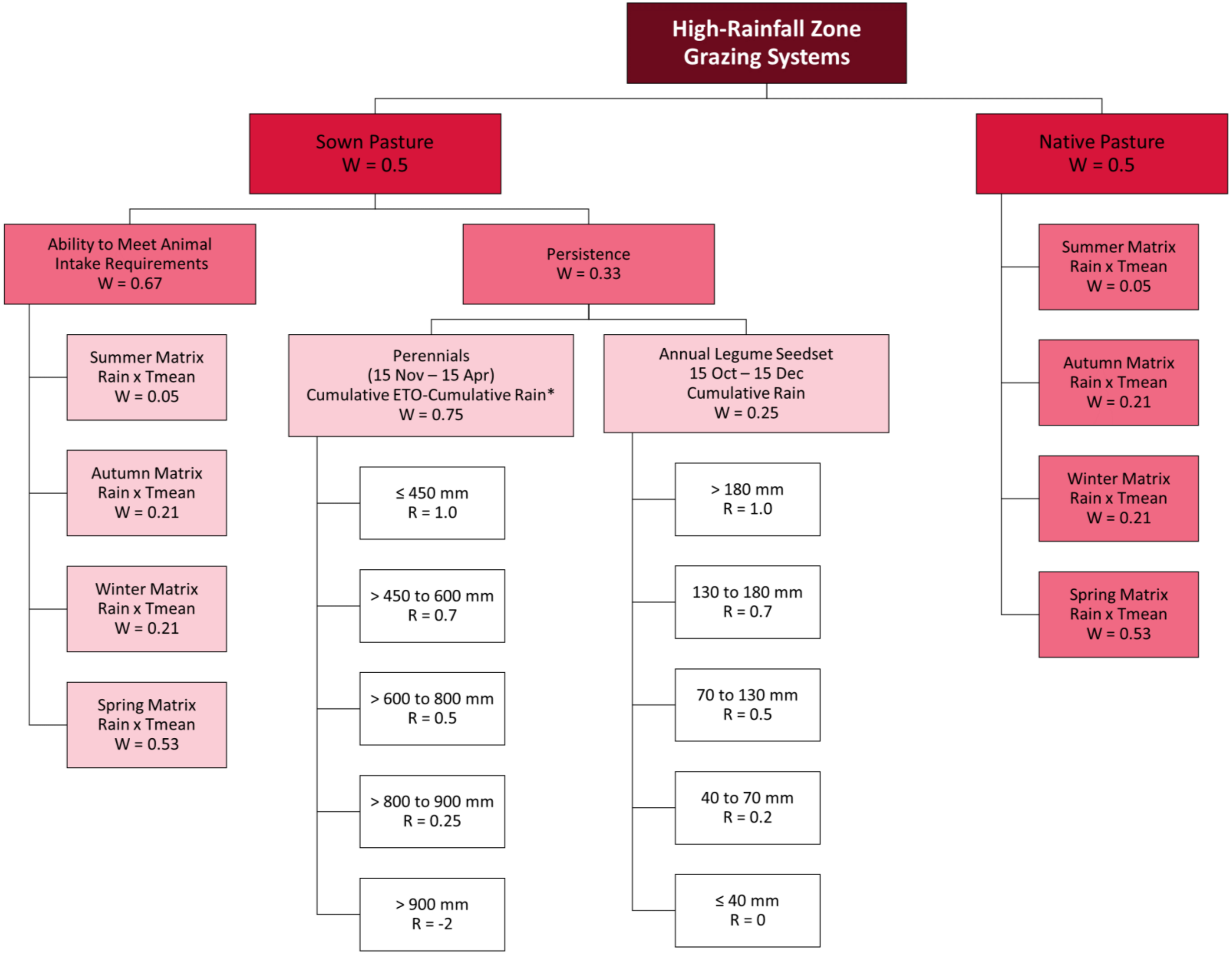


Figure 3: MCA model hierarchical structure and model components for HRZ. The top-level of the hierarchy is the commodity. The second level contains the production phases identified as climate-sensitive by the literature review and expert judgment. The third level contains climate variables. Full matrices and ratings can be found in the appendix. (W = model weightings, R = model ratings).

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 HRZ regions are displayed on each map to indicate the areas where HRZ is currently grazed.

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[5], and the median of these models was used to produce ensemble future projection climate suitability maps.

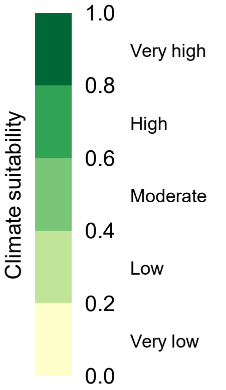


Figure 4: Colour scheme for the climate suitability maps

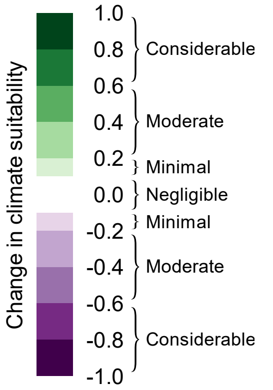


Figure 5: Colour scheme for the change in climate suitability maps

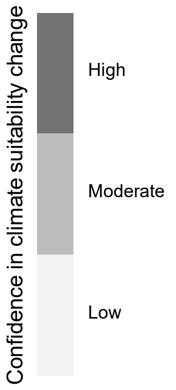


Figure 6: Colour scheme for the confidence in the change in climate suitability maps

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.

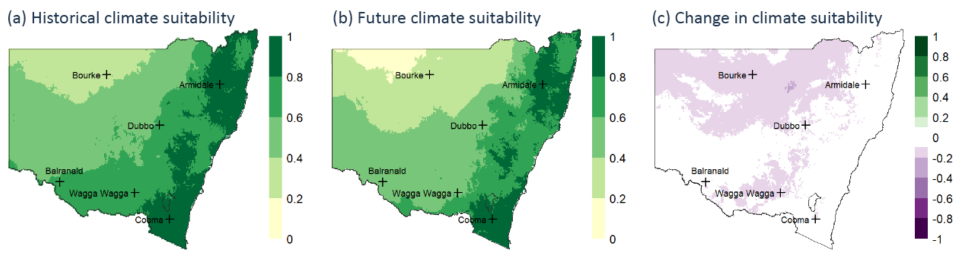
[5] Data was sourced from Climate Change in Australia: Application Ready Data

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.

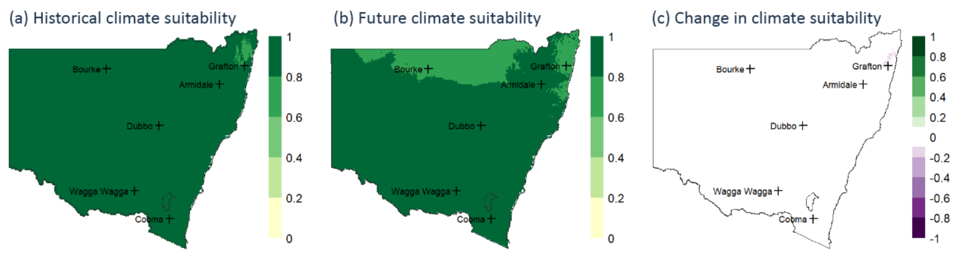
Why does the 'change in climate suitability' map show changes in some places where the historical and future climate suitability maps have the same colour? There are instances where historical and future climate suitability maps show the same category of climate suitability, yet the change in suitability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

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

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

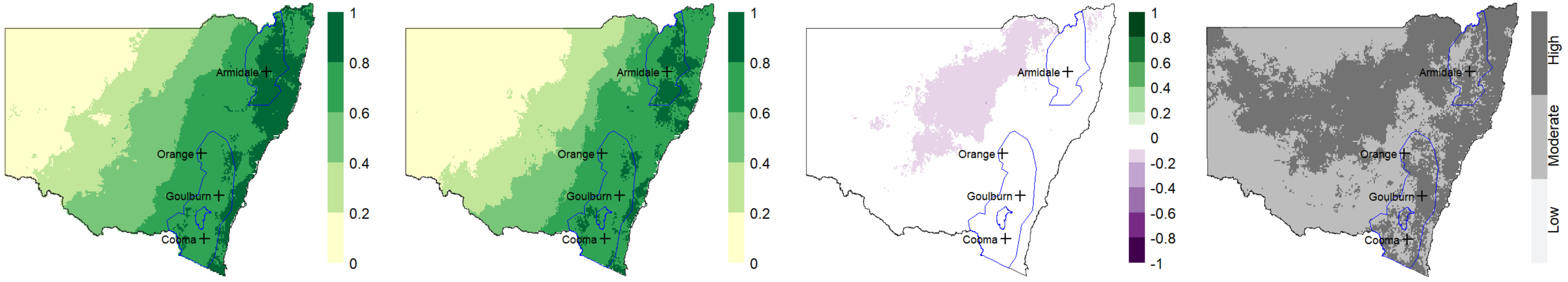
Overall climate impacts

The overall climate suitability for HRZ (Figure 7) is likely to remain high to very high across the HRZ regions in 2050 under both emissions scenarios (*moderate to high confidence*). There is likely to be minimal to moderate negative change (*moderate to high confidence)* in the fringe of current growing regions. Some areas on the fringe to the growing regions may experience a slight reduction in the ability of pastures to grow and persist.

High rainfall zone grazing systems – Overall climate suitability

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 to moderate negative change (*moderate to high confidence)* in the fringe of current growing regions. Some areas on the fringe to the growing regions may experience a slight reduction in the ability of pastures to grow and persist.

RCP8.5 high emissions scenario

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

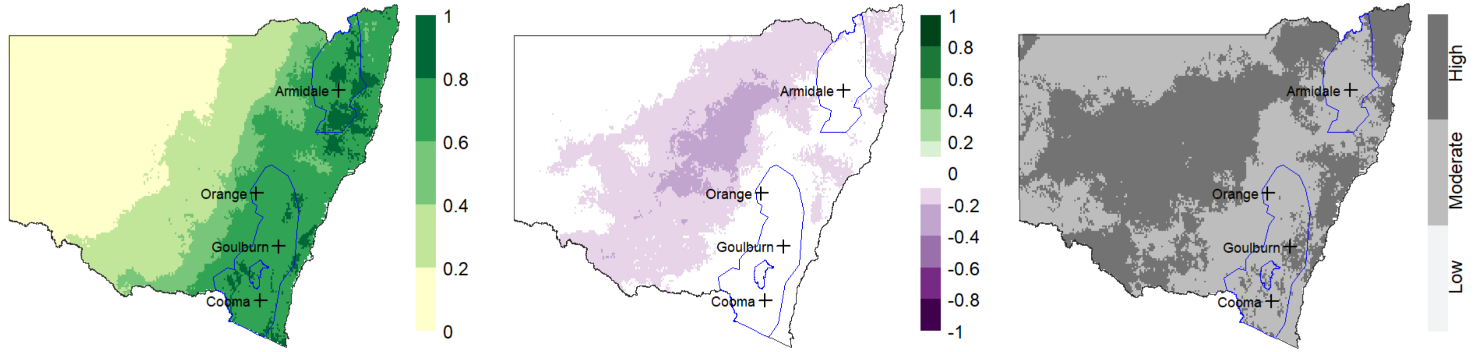


Figure 7: Overall climate suitability for HRZ in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected future 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). The HRZ region is displayed on each map with blue polygons.

Climate impacts on the pastures ability to meet animal requirements.

Climate change impacts to the HRZ affect native and sown pastures in different ways.

Native Pastures

The climate suitability for native pastures (Figure 8) is likely to remain high across the entire HRZ region in 2050, suitability in the Monaro region is expected to slightly increase (*high to moderate confidence*).

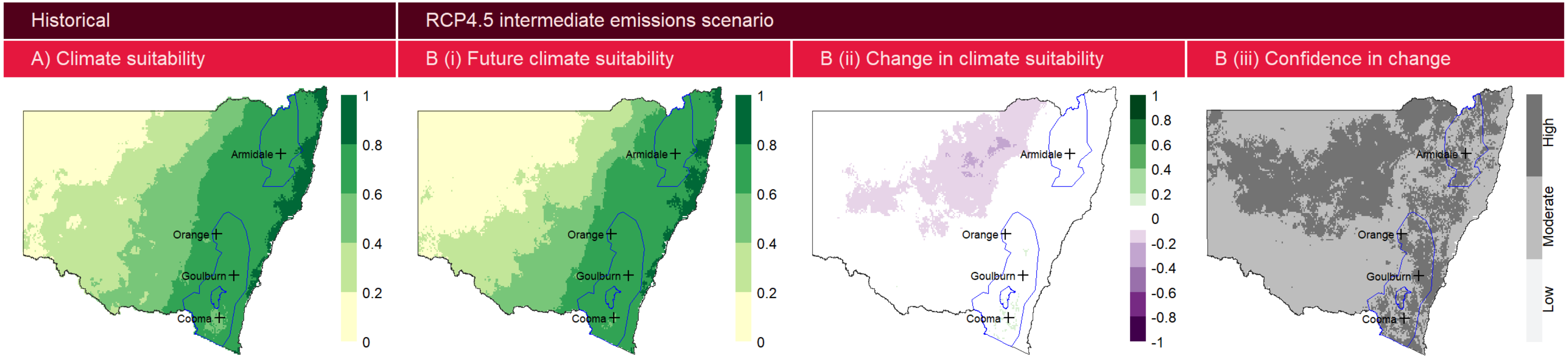
- In **autumn** native pastures are likely to maintain similar suitability to what has been historically experienced (*moderate to high confidence*).
- Climate suitability in the southern HRZ region is likely to increase from minimal to moderate in **winter** (*moderate to high confidence).* The northern HRZ region is likely to maintain a high climate suitability (*moderate confidence*).
- **Spring** is likely to maintain high suitability as has been historically experienced in HRZ regions (*moderate to high confidence*).
- Throughout **summer**, native pastures are likely to maintain similar suitability to what has been historically experienced (*moderate confidence*).

Sown Pastures

Overall, the climate suitability for sown pastures (Figure 9) is likely to remain high to very high across the northern HRZ region in 2050 (*moderate to high confidence*). The ability of the sown pastures to persist is likely to retain high to very high suitability across both HRZ regions in 2050 (*moderate confidence).*

- **Autumn** is likely to experience a minimal to moderate decrease in sown pastures ability to meet animal feed requirements under both emissions scenarios in 2050 (*moderate to high confidence*). This is driven by expected increases in temperatures and more variable rainfall.
- **Winter** and **spring** ability to meet animal feed requirements is likely to remain similar to what has been historically experienced in HRZ regions (*moderate confidence*).
- **Summer** is likely to have a minimal to moderate decrease in sown pastures ability to meet animal requirements under both emissions scenarios due to increased temperatures and more variable rainfall (*moderate to high confidence*).

High rainfall zone grazing systems – Native pastures climate suitability



Findings: There is likely to be minimal to moderate negative change (*moderate to high confidence)* in areas adjacent to the current growing region and the centre of the state.

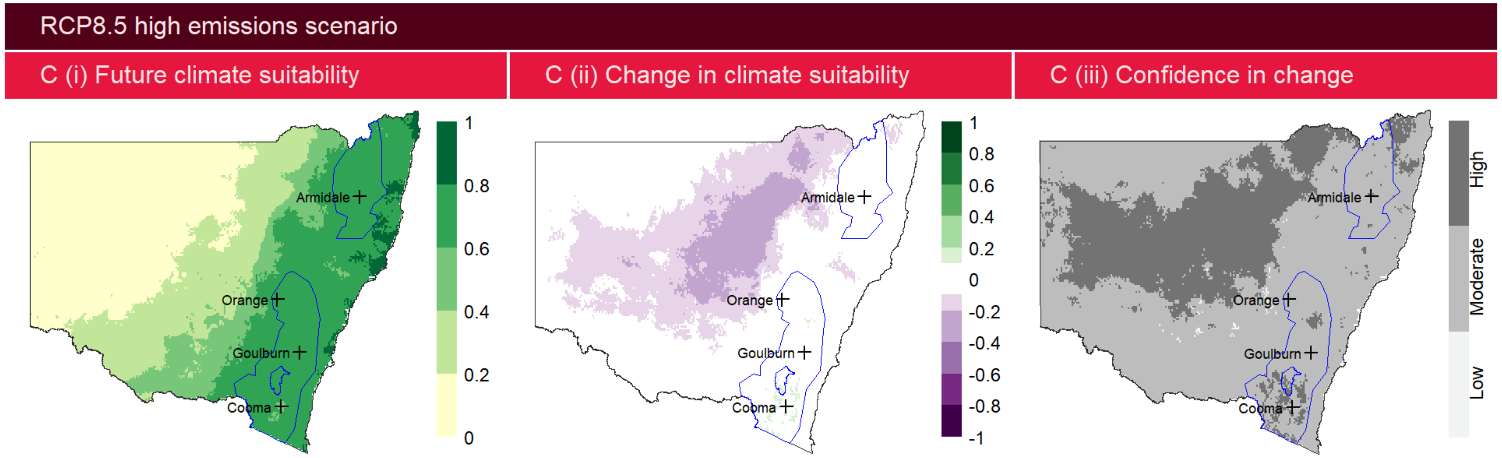
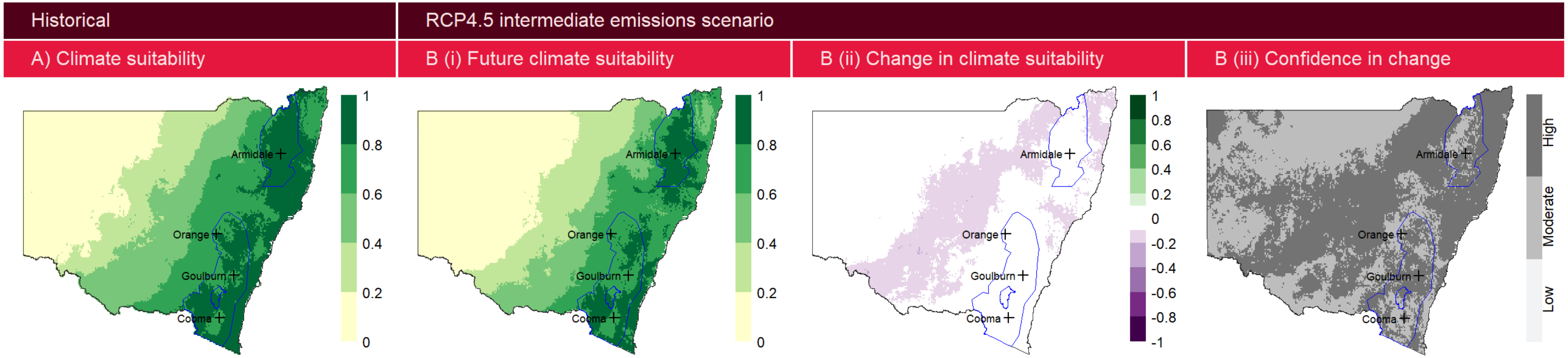


Figure 8: Overall climate suitability for native species under the HRZ in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) 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). The HRZ region is displayed on each map with blue polygons.

High rainfall zone grazing systems – Sown pastures climate suitability



Findings: There is likely to be minimal to moderate negative change (*moderate to high confidence)* in areas adjacent to the current growing region and the centre of the state.

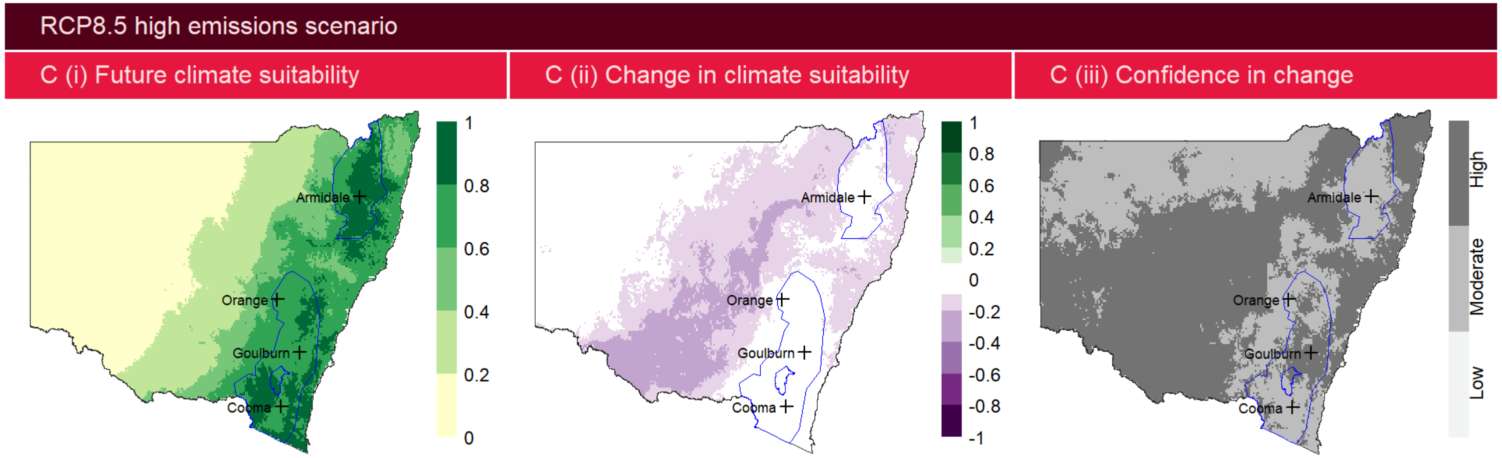


Figure 9: Overall climate suitability of sown species for HRZ in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the 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). The HRZ region is displayed on each map with blue polygons.

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 HRZ, with implications for livestock producers.

Historical and future trends

Overall, the ability for HRZ to meet animal intake requirements is likely to remain the same as what it has been historically in summer, autumn, winter and spring (*moderate confidence*).

Future climate vulnerabilities

Sown pastures are likely to experience a minimal to moderate decrease in the ability to meet animal intake requirements during summer and autumn, decreasing from very high to high suitability (*high to moderate confidence*).

Future climate opportunities

Sown pastures in the HRZ region are likely to remain very highly suitable during winter and spring under both emissions scenarios (*moderate confidence*).

Native pastures in winter are likely to have a minimal increase in suitability around the Cooma region and is expected to maintain high climate suitability (*moderate to high confidence*).

Adaptating to the changing climate

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

Livestock producers could investigate strategies such as:

- Increasing soil fertility to improve the pasture growth response when there is available water. This has previously been identified as a key adaptation strategy.
- Changing stocking rates and joining times to better align with peak feed demand and feed supply periods, which could help mitigate decreases in feed production.
- Using tropical pasture species, particularly in the north of the state. These species are expected to be more resilient to climate change and variable rainfall.
- Selecting hard-seeded legumes, which exhibit longer dormancy until suitable rainfall and temperature conditions are met for germination. This may increase seed bank resilience.

Extensive livestock industry snapshot: what are the projected changes for NSW?

The HRZ climate vulnerability assessment has been designed to be considered alongside the following livestock climate vulnerability assessments. The full reports are available from our website, but a snapshot of key findings is included below.

Beef cattle | *Bos taurus*

Climate suitability for cattle is expected to maintain very high climate suitability across the entire state under both emissions scenarios.

Climate impacts: what to expect

Cattle vulnerabilities

- **Joining** 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 October to December.
- **Calf feed intake** is likely to experience minimal decrease, to moderate to high climate suitability, in northeast NSW under the high emissions scenario (*high confidence*). Feed intake of calves may decrease due to increased heat stress.

Cattle opportunities

- Climate suitability in **survivability** and **lactation** are likely to remain very highly suitable (*high confidence*).

Sheep | Merino

NSW sheep regions are expected to maintain high to very high suitability across the entire state under both emissions scenarios.

Climate impacts: what to expect

Sheep 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 may impact Merino 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 exceeding 35°C during pre-joining (*moderate to high confidence*). This may impact Merino 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*).

Sheep opportunities

- There is likely to be a reduction in the chill index 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.
- Merino climate suitability in survivability and feed intake is likely to remain similar to what has been historically experienced (*moderate to high confidence*).

Invasive weeds snapshot: what are the projected changes for NSW?

Invasive weeds can impact grazing systems in several ways. Some weeds reduce the productivity and palatability of grazing systems, thus reducing carrying capacity, while others contaminate hides and wool, impacting quality.

The life stages of the weeds are impacted by climate in different ways, and the weed climate vulnerability assessments are designed to be considered alongside the grazing system climate vulnerability assessments.

Parthenium weed | *Parthenium hysterophorus*

Changes in climate suitability for parthenium weed are likely to create challenges for grazing systems. Increases in climate suitability are likely for some life stages of Parthenium weed along the Great Dividing Range and eastern NSW by 2050 under both emission scenarios. Climate suitability will decrease in western NSW.

Impact on Extensive Livestock

Parthenium weed is not yet established in any part of the high rainfall, mixed cropping, and rangeland pasture zones in NSW, due to successful eradication efforts following incursions. However, by 2050, increased climate suitability along the Great Dividing Range may heighten the risk of its establishment, necessitating expanded surveillance to ensure early detection and eradication response to prevent its establishment in NSW.

Serrated tussock | *Nassella trichotoma*

Changes in serrated tussock climate suitability are likely to create opportunities for grazing systems, particularly in the high rainfall zone. By 2050, climate suitability will likely decrease during summer for all life stages. Decreased climate suitability in autumn and spring will also likely reduce suitability for the seedling stage. This change may reduce the management burden for land managers and create opportunities for grazing enterprises. These changes are more prominent under the high emissions scenario.

Impact on Extensive Livestock

Seedlings of tussock are the key determinant for weed survival. The expected decrease in climate suitability during this stage in summer by 2050 is likely to result in fewer infestations in the high rainfall zone. This decrease could enable more effective management and eradication efforts. This may help to reinvigorate the number, diversity, and quality of pasture species.

For more information

The full reports for invasive weeds and other biosecurity risks are available on the Climate Vulnerability Assessment Summary Report or on the website.

HRZ: where to from here?

Future priorities

We have assessed the future climate suitability for HRZ as a prerequisite for effective planning decisions and for developing adaptation strategies to address future climate change impacts.

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

- Different pasture types, such as tropical species or hard-seeded legumes, could be modelled individually to determine impacts on specific plant functional type groups.
- Managing total grazing pressures, adjusting stocking rates and improving ground cover to assess best management practices under future climate scenarios.
- The inability to capture impacts from extreme climatic events was a challenge and further work should be considered to understand the impacts of increased frequency of extreme climate events, such as droughts, on grazing systems in the future. This is important as grazing systems are likely to require major management intervention such as the use of sacrifice paddocks or resowing after a flood or drought.

Addressing the gaps, barriers and challenges

The new information generated by this project has helped identify the climate vulnerabilities for HRZ. 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 were challenging for this model;

- The maximum and minimum thresholds of temperature and rainfall for ability to meet livestock feed requirements
- The interaction between water stress and grazing on perennial grass and legume persistence is not clear and needs further investigation.
- More work is needed to quantify the impacts of water stress on perennial grass persistence in NSW.

This report aims to highlight 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 extent to Australia-wide to inform future industry planning nationally.

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 HRZ.

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.

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:

- Beef Cattle
- Sheep
- Mixed Cropping Zone Grazing Systems
- Rangeland Grazing Systems

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

Contact us

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

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Appendix

Sown Pasture Matrices

Summer		Cumulative Rain (mm)				
		< 59	59 to 162	162 to 221	221 to 395	> 395
Tmean (°C)	< 16.9	0.60	0.80	0.95	1.00	1.00
	16.9 to 19.4	0.50	0.75	0.95	1.00	1.00
	19.4 to 20.7	0.40	0.65	0.90	0.95	1.00
	20.7 to 25.4	0.30	0.45	0.60	0.65	0.90
	> 25.4	0.20	0.20	0.20	0.35	0.65

Autumn		Cumulative Rain (mm)				
		< 40	40 to 108	108 to 145	145 to 302	> 302
Tmean (°C)	< 10.9	0.30	0.80	0.95	0.90	0.90
	10.9 to 13.4	0.30	0.80	0.95	0.95	0.90
	13.4 to 14.5	0.30	0.60	0.90	0.90	0.95
	14.5 to 18.2	0.25	0.45	0.60	0.75	0.90
	> 18.2	0.00	0.30	0.60	0.75	0.90

Winter		Cumulative Rain (mm)				
		< 53	53 to 125	125 to 155	155 to 305	> 305
Tmean (°C)	< 4.5	0.50	0.65	0.65	0.65	0.65
	4.5 to 6.7	0.55	0.85	0.90	0.90	0.90
	6.7 to 7.4	0.60	0.90	0.90	0.90	0.95
	7.4 to 10.3	0.60	0.85	0.90	0.90	0.95
	> 10.3	0.65	0.85	0.90	0.90	0.95

Spring		Cumulative Rain (mm)				
		< 61	61 to 144	144 to 185	185 to 335	> 335
Tmean (°C)	< 10.6	0.50	0.80	0.90	0.90	0.95
	10.6 to 14.1	0.50	0.85	0.95	0.95	0.95
	14.1 to 18.0	0.50	0.85	0.95	0.95	0.95
	18.0 to 20.0	0.45	0.65	0.65	0.65	0.80
	> 20.0	0.10	0.15	0.20	0.15	0.30

Native Pasture Matrices

Summer		Cumulative Rain (mm)				
		< 59	59 to 162	162 to 221	221 to 395	> 395
Tmean (°C)	< 16.9	-2	0.60	0.65	0.70	0.90
	16.9 to 19.3	-2	0.60	0.75	0.75	0.90
	19.3 to 25.4	-2	0.60	0.75	0.70	0.90
	25.4 to 28.0	-2	0.45	0.50	0.65	0.90
	> 28.0	-2	-2	0.20	0.20	0.40

Winter		Cumulative Rain (mm)				
		< 53	53 to 125	125 to 155	155 to 305	> 305
Tmean (°C)	< 4.5	0.20	0.20	0.40	0.50	0.60
	4.5 to 6.7	0.20	0.70	0.75	0.75	0.70
	6.7 to 7.4	0.20	0.75	0.75	0.75	0.75
	7.4 to 10.3	0.20	0.75	0.75	0.75	0.95
	> 10.3	0.20	0.80	0.95	0.95	0.95

Autumn		Cumulative Rain (mm)				
		< 40	40 to 108	108 to 145	145 to 302	> 302
Tmean (°C)	< 10.9	0.30	0.75	0.80	0.80	0.95
	10.9 to 14.5	0.30	0.75	0.80	0.80	0.95
	14.5 to 18.2	0.30	0.75	0.75	0.75	0.95
	18.2 to 20.0	0.30	0.60	0.60	0.65	0.95
	> 20.0	0.30	0.35	0.40	0.65	0.95

Spring		Cumulative Rain (mm)				
		< 61	61 to 144	144 to 185	185 to 335	> 335
Tmean (°C)	< 10.6	0.30	0.40	0.60	0.60	0.70
	10.6 to 14.1	0.30	0.55	0.80	0.80	0.80
	14.1 to 18.0	0.30	0.65	0.70	0.80	0.80
	18.0 to 20.0	0.30	0.65	0.70	0.80	0.95
	> 20.0	0.30	0.35	0.60	0.80	0.95

Primary Industries Climate Change Research Strategy

Climate Vulnerability Assessment

High Rainfall Zone Grazing Systems Results Report

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