Department of Primary Industries
and Regional Development

Radiata Pine

Results Report

Climate Vulnerability Assessment

NSW GOVERNMENT

Authors

The NSW Department of Primary Industries and Regional Development Climate Vulnerability Assessment and Forestry teams.

Funding

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

Suggested citation

NSW Department of Primary Industries and Regional Development (2024) Climate Vulnerability Assessment Radiata pine Results Report. https://www.dpird.nsw.gov.au/DPIRD/climate/climate-vulnerability-assessment/publications-and-reports/Climate-Vulnerability-Assessment-Radiata-Pine-Results-Report.pdf, accessed on [insert access date].

Acknowledgement of Country

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

TITLE: Radiata Pine Results Report
ISBN: 978-1-76058-873-1

Contents

Contact us

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

Introduction

Primary industries in NSW operate in one of the most variable climates in the world and are already dealing with a changing and variable climate. The Primary Industries Climate Change Research Strategy invested $29.2 million in projects to help the state's primary industries sector adapt to climate change. As part of this work, the Climate Vulnerability Assessment project undertook impact assessments for primary industries in the broadacre cropping, marine fisheries, forestry, extensive livestock, and horticulture and viticulture sectors, designed to improve our understanding of their commodities' sensitivity to changes in climate.

The Climate Vulnerability Assessment has delivered consistent and comparable understandings of potential climate change impacts across the state, providing a deep insight into sectoral impacts. This strategic information is invaluable for policymakers and industry bodies, providing insights into 28 commodities and 14 biosecurity risks considered as valuable or important to NSW.

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

Purpose of this report

This report contains results for the Radiata pine study within the Climate Vulnerability Assessment. The report introduces the Radiata pine industry in NSW and provides an overview of the model, its key features, assumptions, and exclusions. The main results and findings are presented to provide insights into future climate vulnerabilities and opportunities. 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 physical suitability of land for softwood plantation forestry is governed by climate, which influences growing conditions, soil and topography, which determines where accessible and affordable land can be sourced. Softwood plantations for commercial forestry in NSW are typically located in the Northern and Central Tablelands, the Southern Highlands and Southwest Slopes.

The changing climate is impacting primary industries.

Australia has one of the most variable climates in the world, and primary producers have always managed climate variability. Now, they are planning for and adapting to future climate change. Climate change refers to human-induced changes in long-term climate patterns at global and regional scales. Human-induced climate change adds a new dimension to the challenge of producing timber within Australia's variable climate. Its characteristics include rising temperatures, changes in rainfall patterns and the intensification of extreme weather events such as heatwaves and heavy rain.

The $23.1 billion NSW primary industries 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 about the impact of climate change on commodity productivity or the changing prevalence of biosecurity risks has limited adaptation to climate change in this sector.

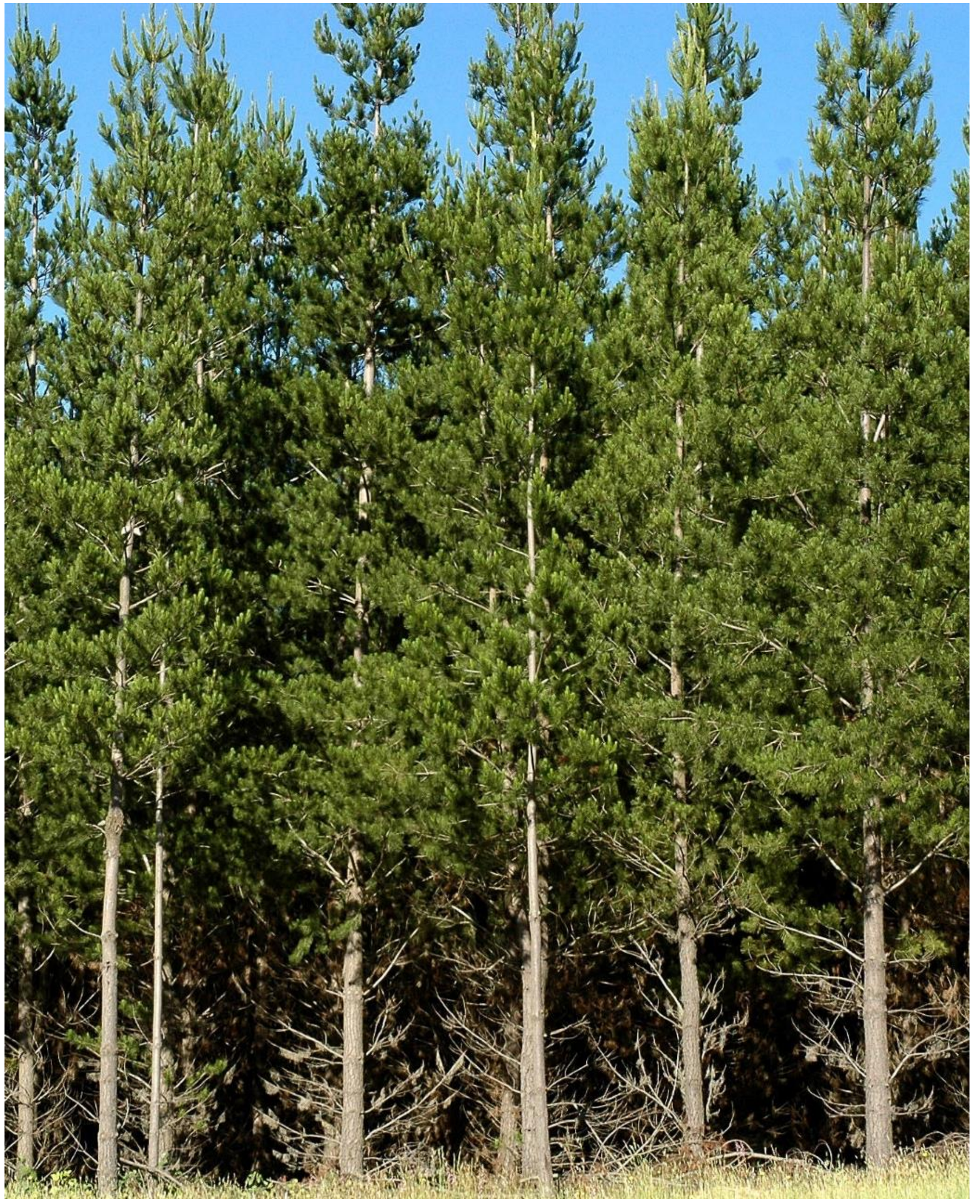
Projected climate change impacts

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

Softwood plantation forestry has very few studies assessing the impact of climate change in Australia. Only 4 of 188 climate impact studies published in Australia looked at the impacts on pine[1]. These 4 studies suggested that plantations in warmer regions will be more adversely affected by climate change than those in cooler areas. Importantly, for the plantation sector, the incidence of extreme weather events is expected to rise, resulting in increased intensity of drought, heatwaves, extreme fire days and heavy rainfall events[2,3]. These impacts could pose significant risks to the forestry sector, enhancing the threat of bushfires and increasing the likelihood of prolonged dry periods. Although we have some understanding from the literature regarding extreme conditions and their potential impact, this assessment has focused on the lack of understanding of how changing average conditions might impact pine.

Assessing the impacts of climate change

The Climate Vulnerability Assessment applied a consistent method to examine the potential impacts of climate change on a wide range of economically important primary industry commodities and biosecurity risks in NSW, including Radiata pine. This enables us to identify those industries most at risk and, thus, 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] Pinkard EA, Battaglia M, Howden SM, Bruce J, & Potter K. (2010) *Adaptation to climate change in Australia's plantation industry*. CSIRO.

[3] Pinkard E, Wardlaw T, Kriticos D, Ireland K & Bruce J (2017) Climate change and pest risk in temperate eucalypt and radiata pine plantations: a review. *Australian Forestry* **80:** 228-241.

Radiata pine in NSW

NSW has more than 349,000 ha of forestry plantations across the state, with approximately 294,300 ha of softwood plantations[4]. The value of softwood logs harvested in NSW in 2021-22 was estimated to be $295 million. Overall, the forestry industry in NSW adds an estimated $3.3 billion to the economy and most recently directly employed approximately 14,900 people in the forest sector[5].

Radiata pine (*Pinus radiata*) is the largest plantation species in NSW, with an estimated planted area of more than 178,000 ha. Areas in NSW with concentrations of plantations in NSW are shown in Figure 1. Radiata pine is primarily planted in these regions of NSW due to favourable climate and soil conditions. These areas typically have suitable rainfall patterns, temperature ranges and soil types that support optimal growth of Radiata pine.

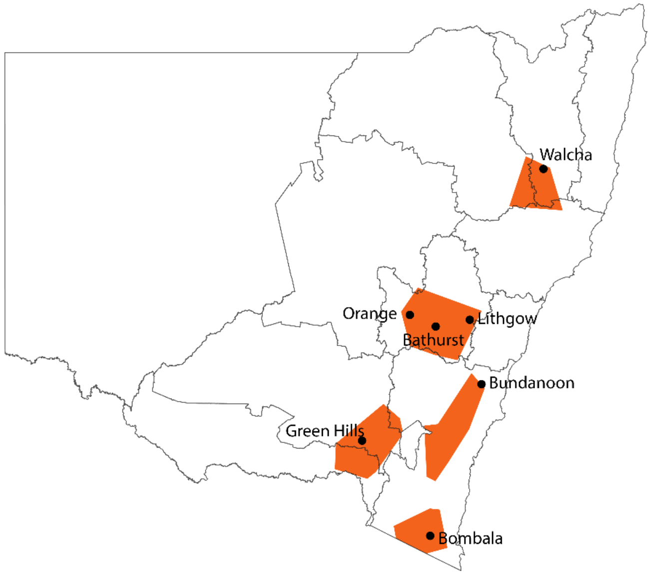
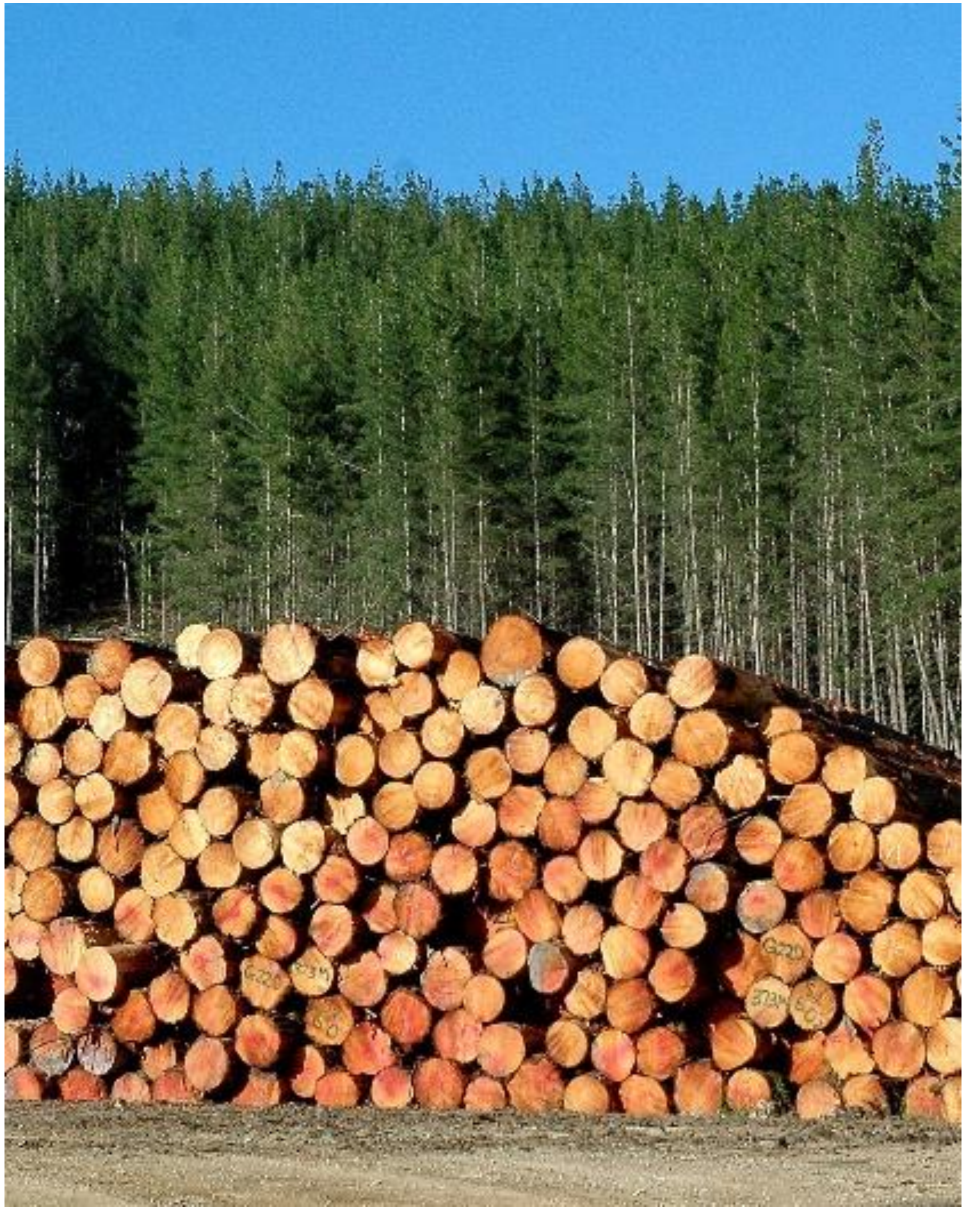


Figure 1: Mapped area of Radiata pine forests in NSW



[4] ABARES, Australian forest and wood product statistics, accessed September 2024.

[5] NSW DPI, Performance, Data & Insights, accessed September 2024.

Climate Vulnerability Assessment framework

The Climate Vulnerability Assessment was intended to provide an overview of the impact of climate change on all stages of production for the commodities and biosecurity risks assessed. To achieve this, a modelling approach was adopted that would produce assessments for the commodities and biosecurity risks in a consistent, and therefore comparable, way.

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 for Radiata pine.

The assessment framework, outlined in Figure 2, provides a rigorous, flexible and transparent process for assessing vulnerability to climate change. It 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 the model development, as a small focus group. The participation of experts throughout the process was critical for integrating expert knowledge into the models developed by the Climate Vulnerability Assessment.

Over 100 Department of Primary Industries and Regional Development staff contributed to the Climate Vulnerability Assessment, and almost 200 experts participated in focus groups to support the review and refinement of the models. External experts were drawn from industry bodies, producers, academia and elsewhere.

MCA modelling approach

The steps in the framework developed for the Climate Vulnerability Assessment are 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 or lifecycle phases, each of which contains the climate variables that influence that phase.

Each growth 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 are derived using the analytical hierarchy process[6] and reflect the consensus reached by the focus group experts.

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

The MCA model is not designed as a yield estimating model but as a climate suitability model. Climate suitability is defined as the extent to which climatic conditions satisfy the requirements of plant or animal growth in the absence of other limiting factors[7]. The MCA model provides an assessment of climate suitability (ranging from unsuitable to highly suitable) for each individual climate variable, for each production phase and for the overall model. Climate suitability is modelled for both historical (recent past) conditions and for projected (near future) climate to understand how the climate suitability for the pine 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 pine and key results showing important changes to future climate suitability for Radiata pine, as identified by the assessment.

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

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

Project scope and exclusions

The project scope was limited to the assessment of vulnerability to climate change. The assessment captures the response of Radiata pine to changes in average future climatic conditions. The project was designed to support policy and regional investment decisions. The following were not considered:

- soil properties
- topography
- socio-economic factors
- site-specific management

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

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

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

Overview of the Radiata pine model

For more information, see the Climate Vulnerability Assessment Methodology Report.

Climate variables

The climate variables used in the Radiata pine MCA model were minimum temperature (Tmin, °C), mean temperature (Tmean, °C), maximum temperature (Tmax °C) and rainfall (Rain, mm).

Categorising climate variables

The hierarchical structure of the MCA model (Figure 3) categorises these climate variables to assess their impact on Radiata pine. This is repeated for each season within each growth stage.

Modules used in the Radiata pine MCA model

The Radiata pine 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:

- **Lethal conditions:** Define extreme climate conditions that are fatal to the growth stage. If the threshold for lethal conditions is reached, then climate suitability is set to zero for that growth stage for that year.
- **Matrix module**: Matrices capture the interaction between two climate variables. For Radiata pine these were seasonal mean temperature and six-month cumulative rainfall (the season of interest and the previous season's rainfall). This module was used in all stages as they are particularly sensitive to the interplay between these two climate variables. The matrix categories define different combinations of climate conditions, for example, temperature between 12 and 25°C and the cumulative rainfall of less than 250 mm. The matrix ratings identify the suitability of each specific combination from unfavourable to optimal conditions.

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 Radiata pine.

Consecutive days

Trees are more responsive to consecutive days of stressful climatic conditions (e.g. heatwaves) than if these conditions occur as isolated days. Due to data limitations, the prevalence of consecutive days of stressful conditions could not be assessed directly. Instead, we assigned model parameters according to the probability that days of extreme conditions occurred consecutively in the historical record.

Radiata pine model assumptions

A model represents a simplified version of reality. Modelling assumptions and exclusions simplify complex systems by reducing the number of influencing factors, making model development tractable. In addition to the general project scope and exclusions on the previous page, the Radiata pine model also excludes consideration of the following:

- Windthrow impacts
- Pests and diseases
- Snowfall and hail damage

Final Radiata pine model

Due to the large scale of planting and high value of *Pinus radiata,* softwood plantation was selected as the forestry-based commodity to be included in the project, and an MCA model was designed based on the variables that may influence climate suitability for Radiata pine.

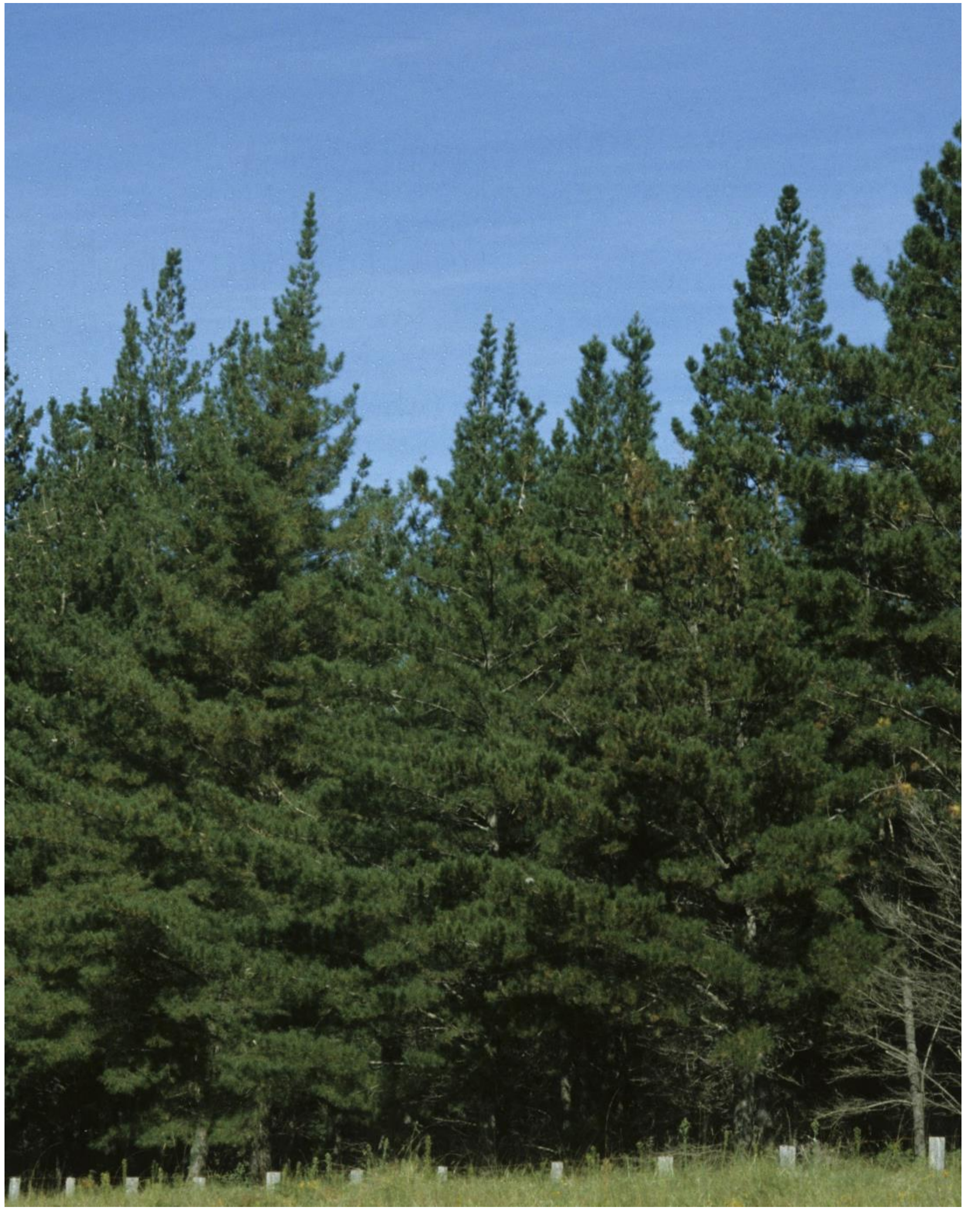
The main MCA model structure with weightings for Radiata pine is shown on the following page (Figure 3). Full details of the temperature and rainfall matrices used in the MCA model can be found in the Appendix.

The Radiata pine MCA model has been divided into key growth stages applied across a seasonal timescale. The growth stages used in this modelling are Seedling (younger than two years), Juvenile (2 to 5 years), Adolescent (5 to 13 years) and Mature (13 to 35 years). This captures the full life-cycle of the majority of the Radiata pine plantation estate. Climate conditions were considered for each season and growth stage.

Fire risk to Radiata pine

Forest fires have serious consequences for the productivity of Radiata pine forests in NSW, and it is highly likely that the frequency and severity of forest fires will increase under climate change.

Due to data and methodological limitations, this assessment did not explicitly model future changes to fire risk. Instead, the Radiata pine MCA model describes combinations of seasonal temperature and rainfall conditions that are correlated with fire risk.



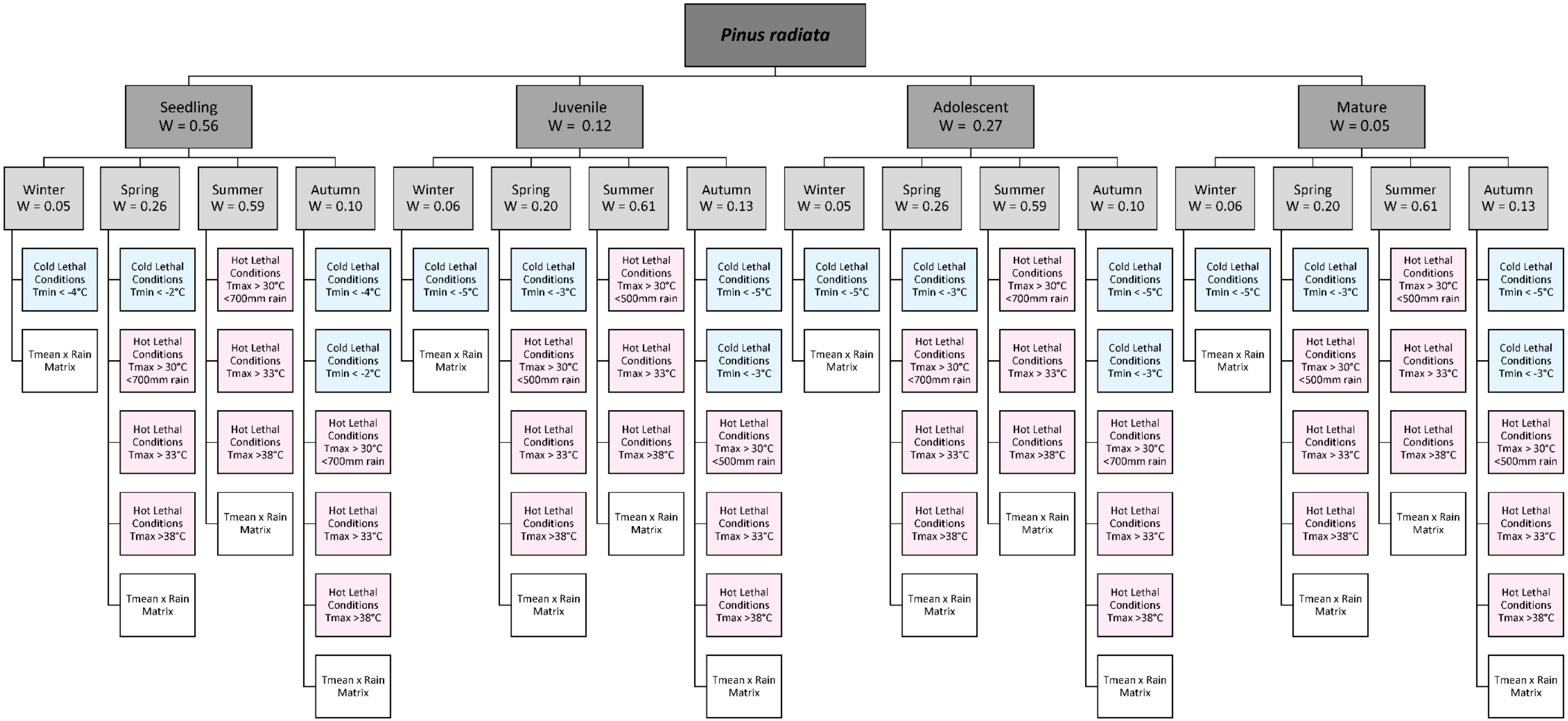


Figure 3: MCA model hierarchical structure and model components for Radiata pine. The top level of the hierarchy is Radiata pine. The second level contains the growth stages identified as climate-sensitive by the literature review and expert judgment. The third level contains each season, whilst the fourth level contains the climate variables which affect each season and growth stage. Additional information about the temperature x rainfall matrices can be found in the Appendix. W refers to the weightings of the model.

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 pine growing regions are displayed on each map to indicate the areas where pine is 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[8], and the median of these models was used to produce ensemble future projection climate suitability maps. It is worth noting that the future projection period will encapsulate current pine rotations.

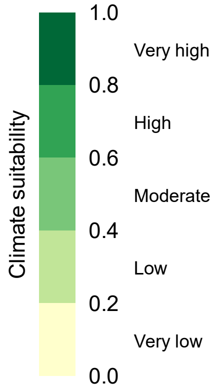


Figure 4: Colour scheme for the climate suitability maps

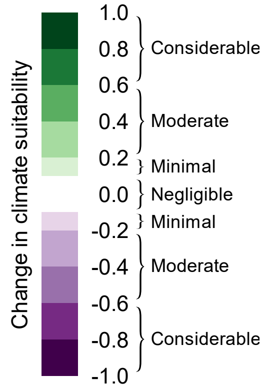


Figure 5: Colour scheme for the change in climate suitability maps

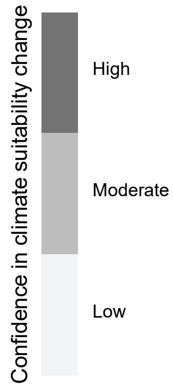


Figure 6: Colour scheme for the confidence in the change in climate suitability maps

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.

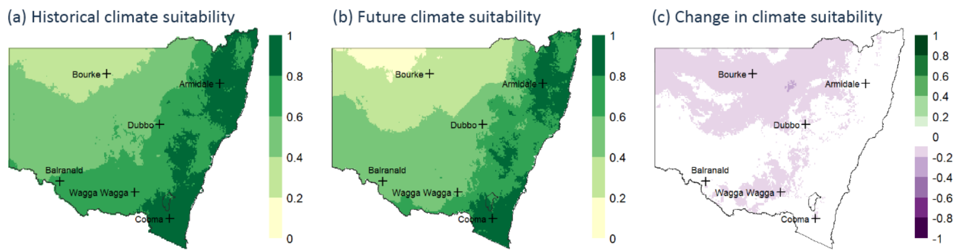
[8] Data was sourced from Climate Change in Australia: Application Ready Data

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.

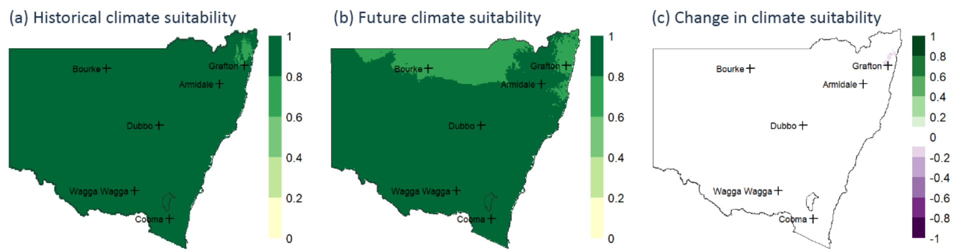
Why does the 'change in climate suitability' map show changes in some places where the historical and future climate suitability maps have the same colour? There are instances where historical and future climate suitability maps show the same category of climate suitability, yet the change in suitability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

Climate change will likely challenge Radiata pine production in NSW, with most areas expected to decrease in climate suitability.

This section provides a selection of key results for the Radiata pine model. The section begins with an overview of the main impacts, vulnerabilities, and opportunities, followed by maps of the seedlings' growth stage that showed notable changes. The relevant interpretation and findings are provided in text on the bottom left corner of each map panel.

Overall Climate Impacts

The outputs from the overall Radiata pine model (see Figure 7) show that existing pine-growing regions in NSW are expected to continue to have moderate to very high climate suitability for growing pine in 2050 under both emissions scenarios. There is likely to be minimal to moderate negative change in climate suitability for pine growth in western areas of the Walcha, Bathurst and Tumut growing regions (*moderate to high confidence)*. However, climate suitability in the remainder of the existing plantation estate is likely to be similar to that experienced historically *(moderate to high confidence)*.

Climate impacts on production phases

Future climate change impacts affect the growth stages of Radiata pine in different ways:

Seedlings

Seedlings (0-2 years) are the most climate-sensitive growth stage, most impacted growth stage and the most significant growth stage for plantation viability. Seedlings are likely to experience a decrease in climate suitability in western pine-growing regions (*moderate to high confidence,* Figure 8). This is mainly driven by changing rainfall patterns and expected increases in hot days during spring and summer (*moderate to high confidence*). However, part of the Walcha and Bundanoon regions are expected to experience increased seedling climate suitability (*moderate confidence*).

Seasonal trends in climate suitability for seedling trees

- In **winter**, the Alpine area between Bombala, Tumut and the Bundanoon are likely to become more suitable for seedlings *(high confidence)*. The northern part of Walcha is also likely to become more suitable for seedling survival *(high confidence)*.
- During **spring**, in western parts of the Tumut and Bathurst growing regions, higher seedling mortality is expected due to more numerous hot days. This is likely to result in limited areas of minimal to moderate decreases in climate suitability under RCP4.5 *(high confidence)* and broader areas of moderate to considerable decreases in climate suitability under RCP8.5 *(moderate confidence)*.
- **Summer** is the most critical time in the seedling growth stage. During these months future mortality increases are likely in Bathurst and Tumut *(high confidence)* and a small part of Walcha under RCP4.5 *(low confidence)*. Under RCP8.5, there is likely to be a more widespread increase in seedling mortality around Bathurst and Tumut *(high confidence)* and the western parts of the Walcha *(low confidence)* and Bundanoon regions *(moderate confidence)*.
- Climate suitability during **autumn** months is likely to decline minimally under RCP4.5 *(high confidence)*, and moderately under RCP8.5 (high confidence) in parts of all present-day growing areas.

Juvenile trees

Juvenile trees (2-5 years) are likely to experience similar climate suitability to what has been historically experienced (*low to high confidence,* Figure 13). Some western regions are expected to moderately decrease in climate suitability due to rising average temperatures, changing rainfall in spring, and increased prevalence of hot days in summer (*low to high confidence*).

Seasonal trends in climate suitability for juvenile trees

- **Winter** months are likely to maintain conditions similar those experienced historically *(moderate confidence)*.
- During **spring**, there are likely to be minimal negative impacts on growth across the state including the Walcha, Bundanoon, Bathurst regions *(moderate confidence)*.
- In **summer**, under the intermediate emissions scenario (RCP 4.5), most present-day growing regions are likely to maintain climate suitability similar to what has historically been experienced, with minimal decreases in climate suitability in the western reaches of the Tumut region *(moderate confidence)*. Minimal to moderate declines in climate suitability are likely in western reaches of the Bathurst and Tumut regions under the high emissions (RCP8.5) scenario *(high confidence)*.
- **Autumn** months are likely to maintain conditions similar to those experienced historically under both RCP4.5 *(moderate confidence)* and RCP8.5 *(high confidence)*.

Adolescent trees

Adolescent trees are sensitive to hot, dry conditions because stands have not yet been thinned and competition for resources, especially soil moisture, is high. Adolescent trees (5 to 11 years) are likely to experience an increased number of hot days in summer and reduced rainfall (*low to moderate confidence*), leading to a decrease in climate suitability for adolescent trees in the western parts of some growing regions (Figure 14). However, most regions will experience similar climate suitability to historical conditions (*moderate to high confidence*).

Seasonal trends in climate suitability for adolescent trees

- The alpine region and higher altitudes along the Great Dividing Range are likely to become more suitable for adolescent trees in **winter**, whilst much of the rest of the state is likely to maintain conditions similar to what has been historically experienced *(high confidence)*.
- **Spring** months are likely to maintain conditions similar to what has been historically experienced *(moderate to high confidence)*.
- In the **summer**, the risk of future mortality increases are likely around Bathurst and Tumut and a small part of the Walcha region under the intermediate (RCP4.5) emissions scenario *(moderate to high confidence)*. Under the high emissions scenario (RCP8.5), there is likely to be increased and more widespread mortality around Bathurst, Tumut, and the western parts of Walcha and the Bundanoon regions *(moderate to high confidence)*.
- **Autumn** months are likely to maintain conditions similar to what has been historically experienced *(moderate confidence)*.

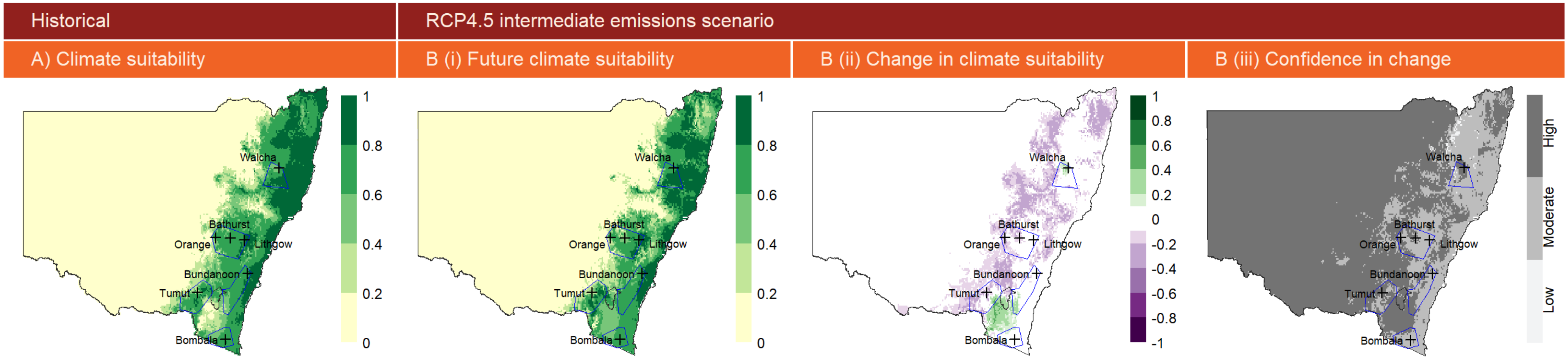
Mature trees

Mature trees are the most robust and least sensitive growth stage of Radiata pine. Mature trees (11 to 30 years) are likely to experience similar climate suitability to historical conditions (*moderate to high confidence,* Figure 15). Heat impacts during spring and summer may lead to decreased suitability in some areas (*low to moderate confidence*).

Seasonal trends in climate suitability for mature trees

- **Winter** months are likely to maintain conditions similar to what has been historically experienced *(moderate confidence)*.
- During **spring,** minimal decreases in climate suitability are likely to impact growth throughout parts of the Bundanoon and Bathurst regions under the high emissions scenario *(moderate confidence)*.
- In **summer**, under intermediate emissions scenarios, the western reaches of the Tumut, Bathurst and Walcha regions are likely to have minimal to moderate decreases in climate suitability *(moderate confidence)*. These trends are exacerbated if the high emissions scenario eventuates *(moderate confidence)*.
- **Autumn** months are likely to maintain conditions similar to what has been historically experienced *(moderate confidence)*.

Radiata pine - overall



Findings: Climate change is expected to present challenges for Radiata pine production in NSW, with some areas expected to decrease in climate suitability by 2050 under both emissions scenarios *(low to high confidence)*. This is likely to reduce pine replanting and long-term production in existing growing regions.

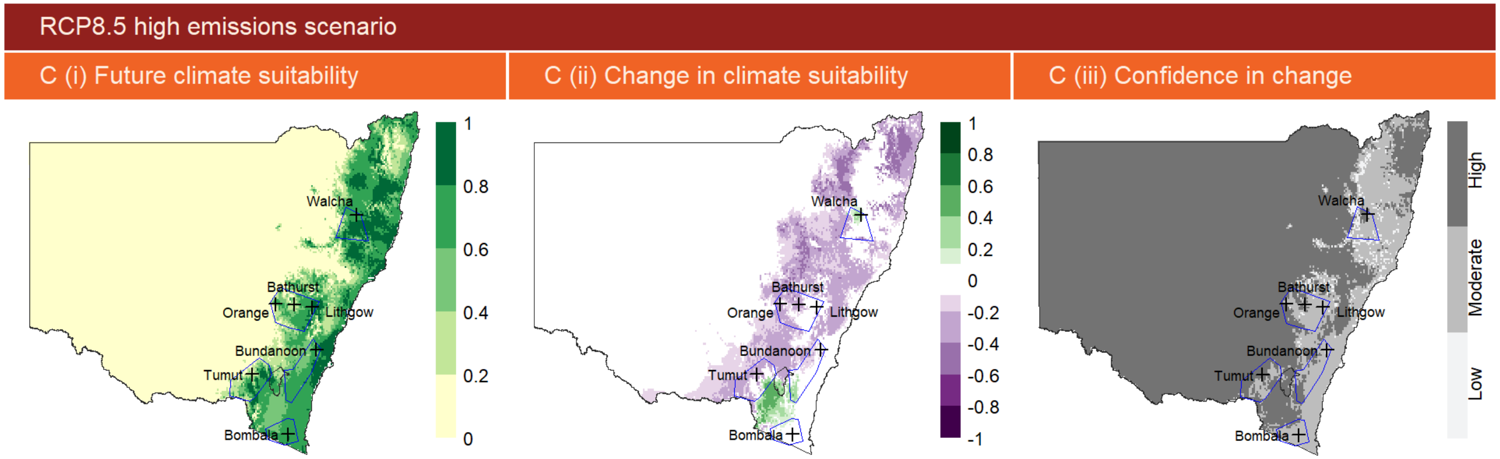
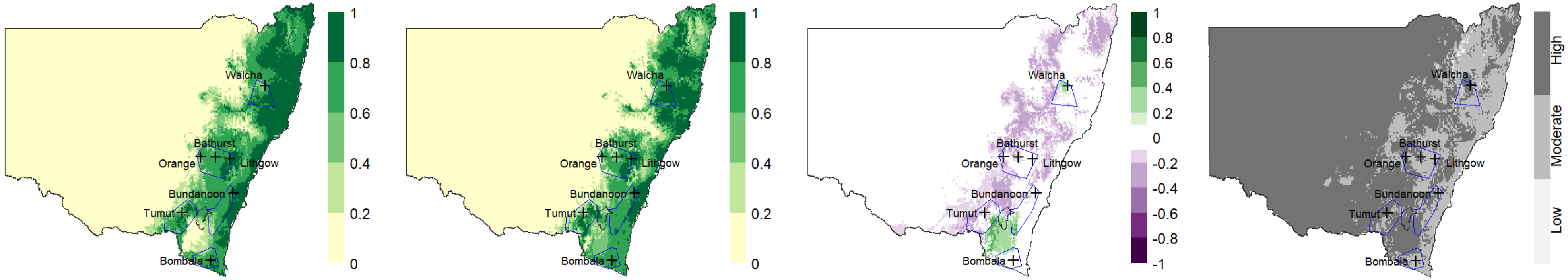


Figure 7: Overall climate suitability for Radiata pine in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows the projected 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 pine is currently grown are indicated by blue polygons.

Radiata pine - seedling

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: The seedling growth stage is the most sensitive to the impacts of climate change. Minimal to moderate negative change within most current growing regions is likely under both emissions scenarios *(moderate to high confidence)***.**

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

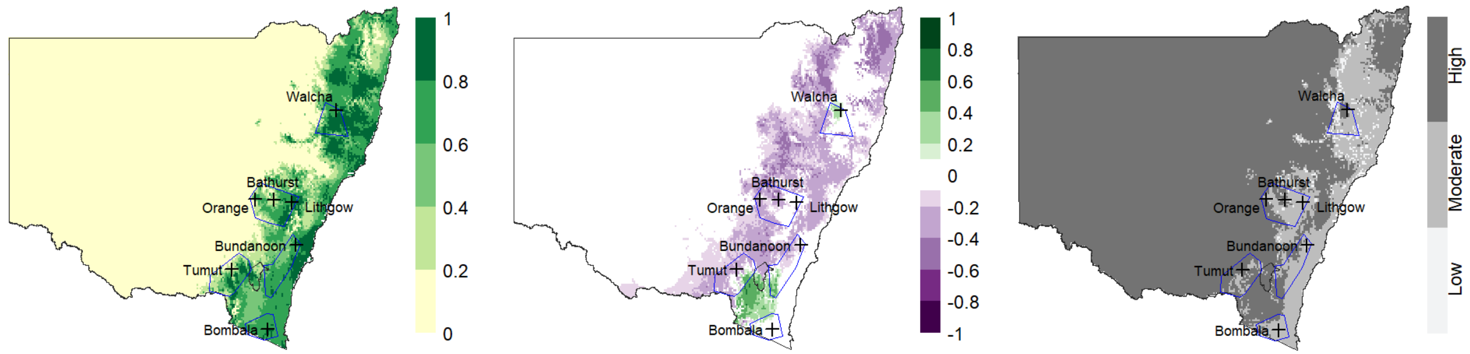
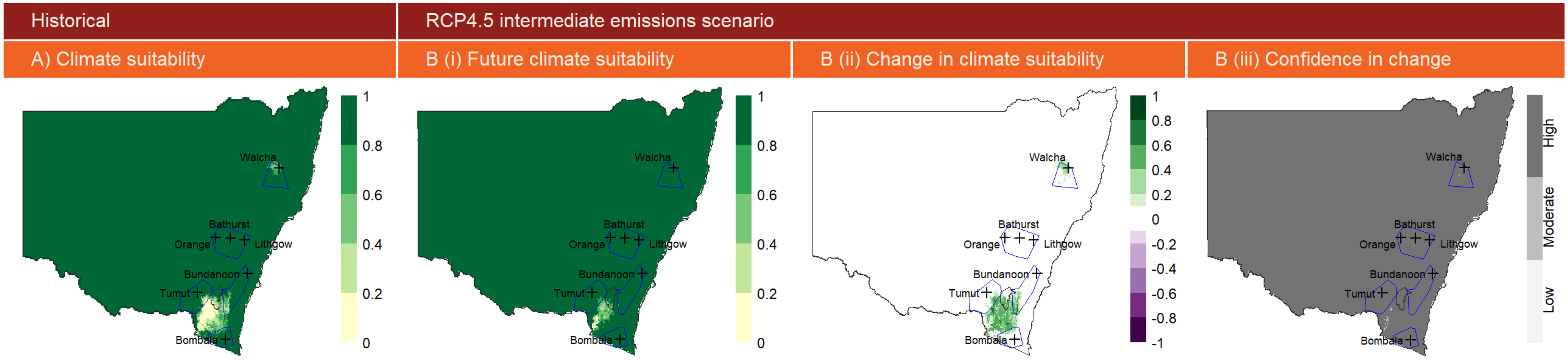


Figure 8: Climate suitability for Radiata pine seedling growth stage in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows 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 pine is currently grown are indicated by blue polygons.

Radiata pine – seedling winter cold lethal conditions (Tmin < –4°C)



Findings: The Alpine and Walcha growing regions are likely to experience minimal to considerable positive change in climate suitability (*high confidence*). This is likely to provide more suitable growing conditions for seedlings in winter.

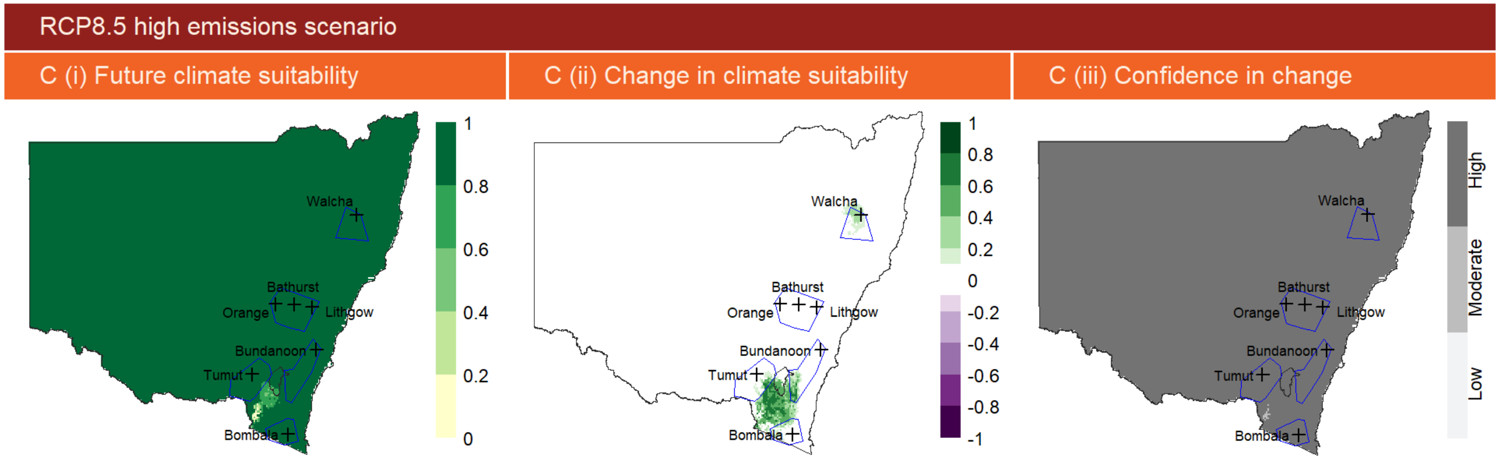
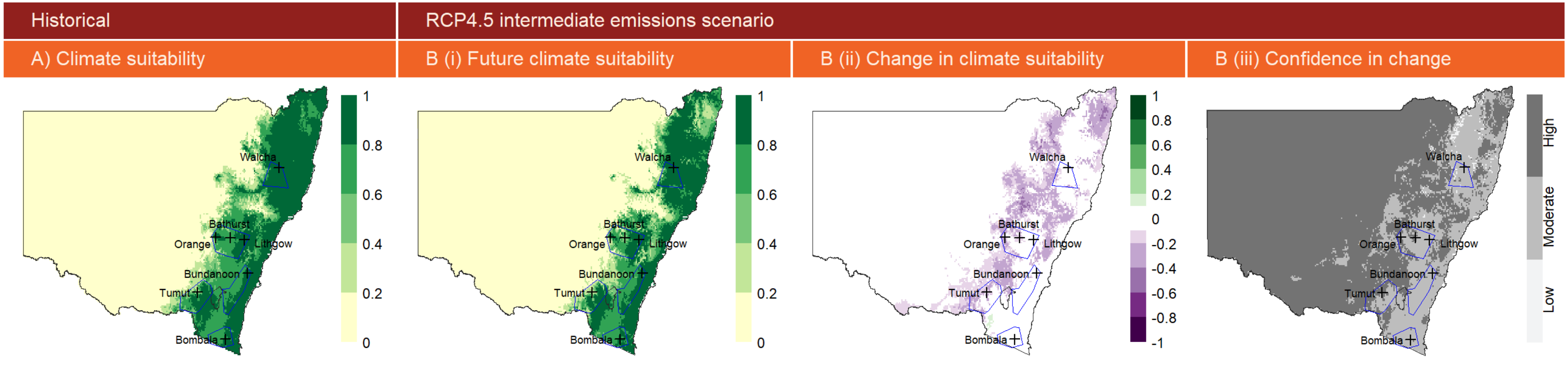


Figure 9: Climate suitability for Radiata pine seedling winter cold conditions in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, 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 pine is currently grown are indicated by blue polygons.

Radiata pine – seedling summer



Findings: Minimal to moderate negative change within most growing regions is likely under both emissions scenarios *(moderate to high confidence).* These changes are likely to arise due to an increase in hot temperatures during the summer months.

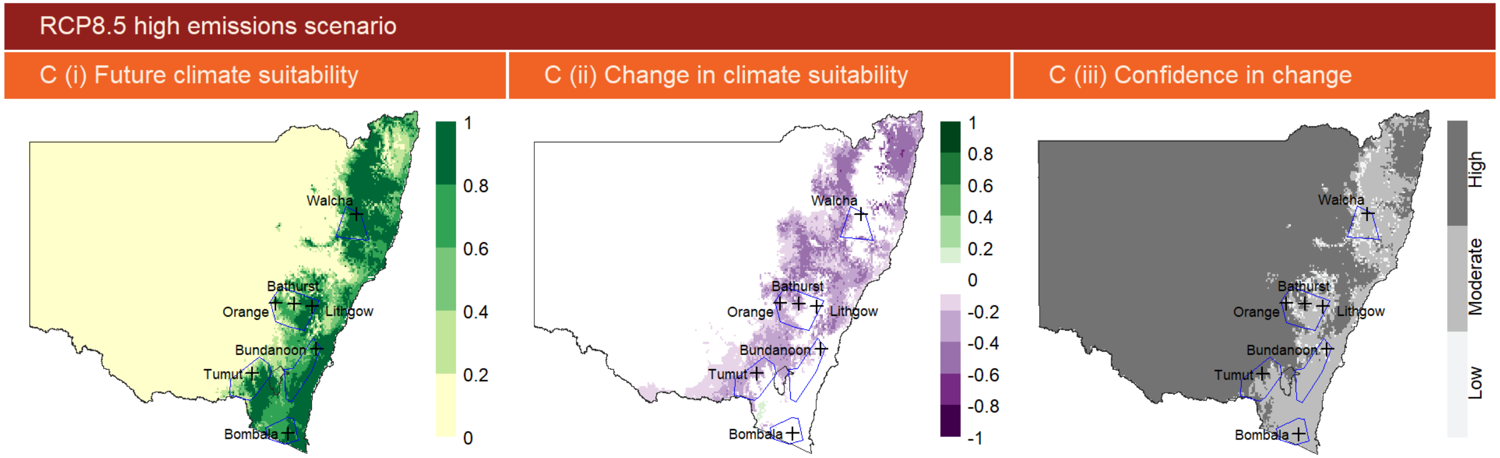
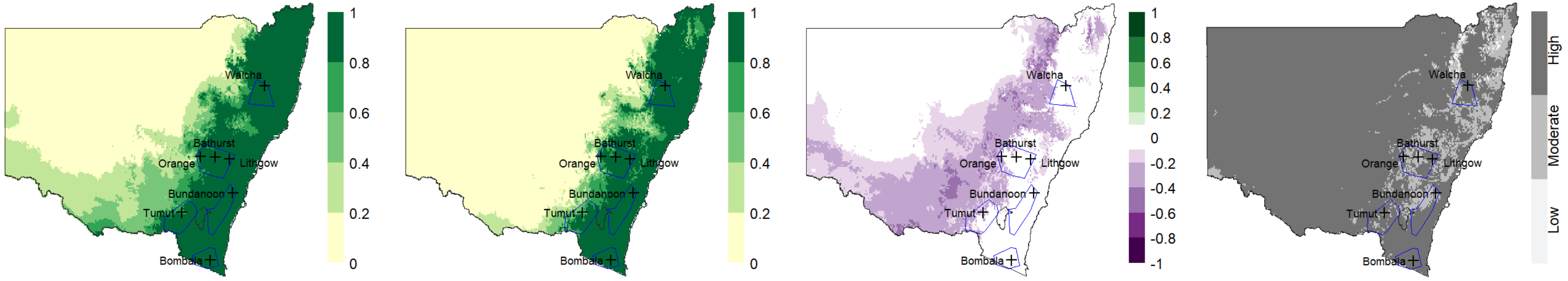


Figure 10: Climate suitability for Radiata pine seedling growth stage in summer in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, 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 pine is currently grown are indicated by blue polygons.

Radiata pine – seedling summer hot lethal conditions (Tmax > 33°C)

Historical | **RCP4.5 intermediate emissions scenario**

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



Findings: Minimal to moderate negative change across most growing regions is likely under both emissions scenarios *(moderate to high confidence).* These changes are likely to arise due to an increase the number of hot days during the summer months impacting survival and growth.

RCP8.5 high emissions scenario

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

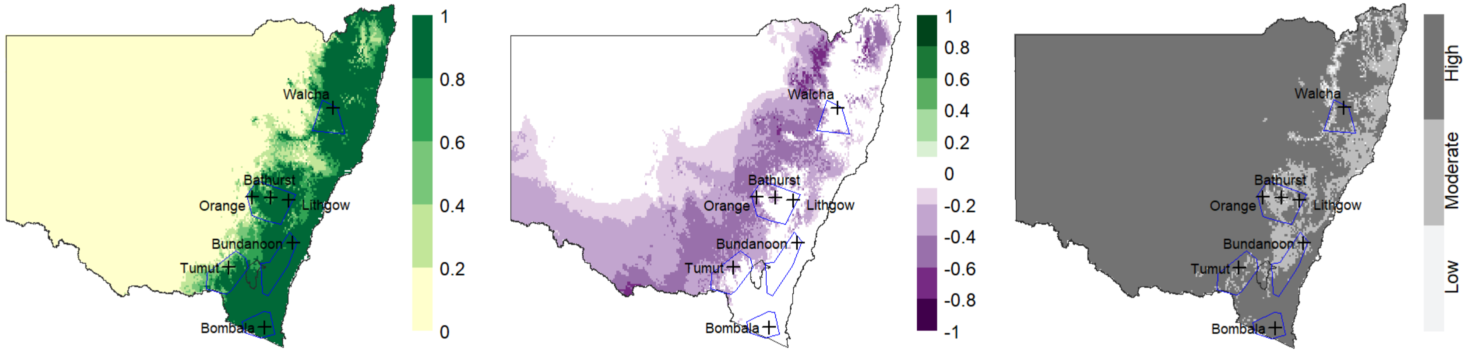
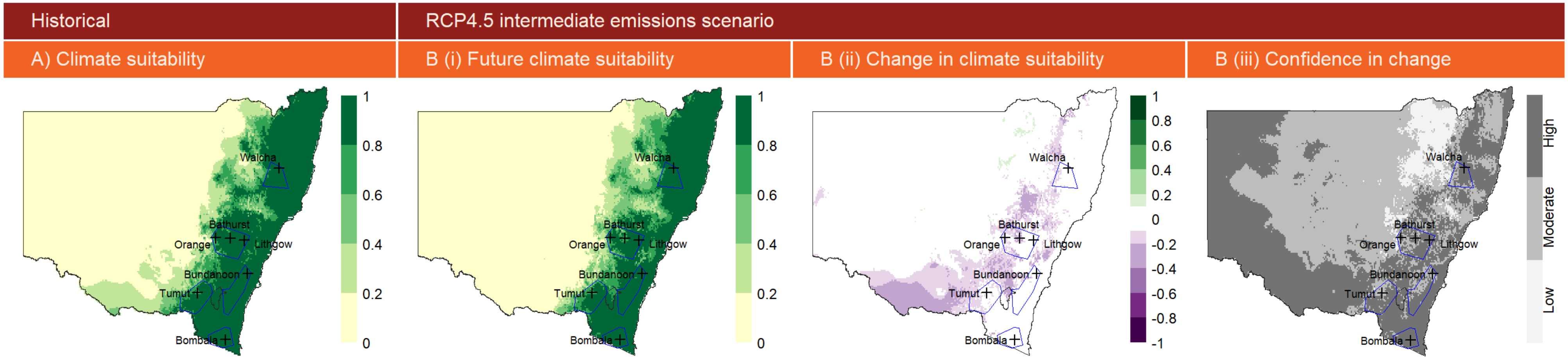


Figure 11: Climate suitability for hot conditions during summer for the Radiata pine seedling growth stage in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows 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 pine is currently grown are indicated by blue polygons..

Radiata pine – seedling summer hot and dry conditions



Findings: Minimal to moderate negative change across most growing regions is likely under intermediate (RCP4.5) and high (RCP8.5) emissions scenarios. These changes are likely to arise due to an increase the prevalence of hot, dry conditions during the summer months.

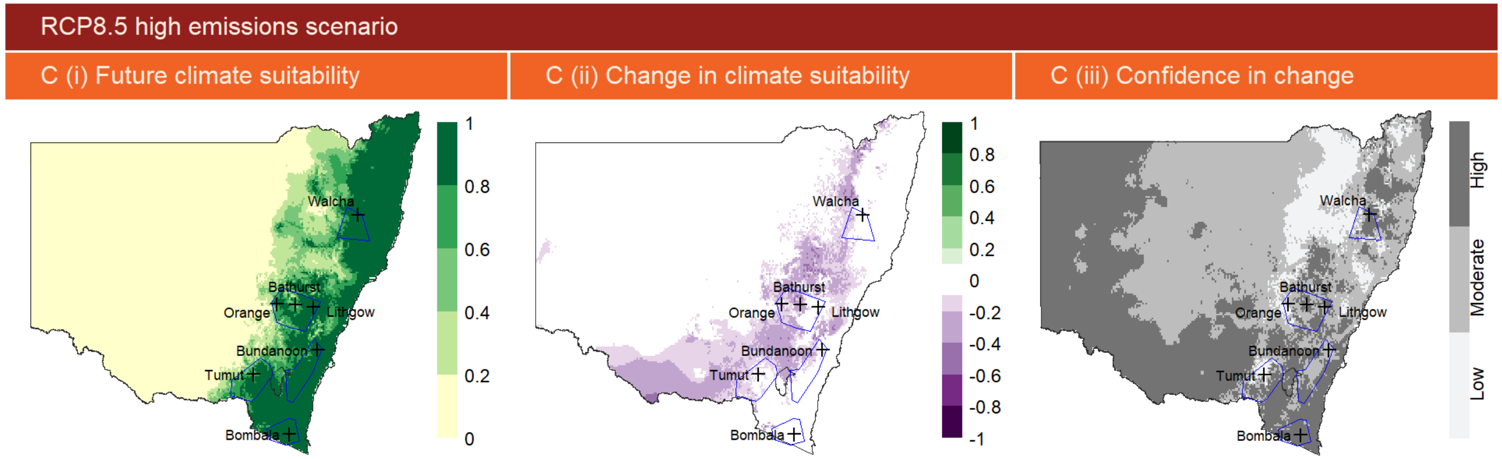
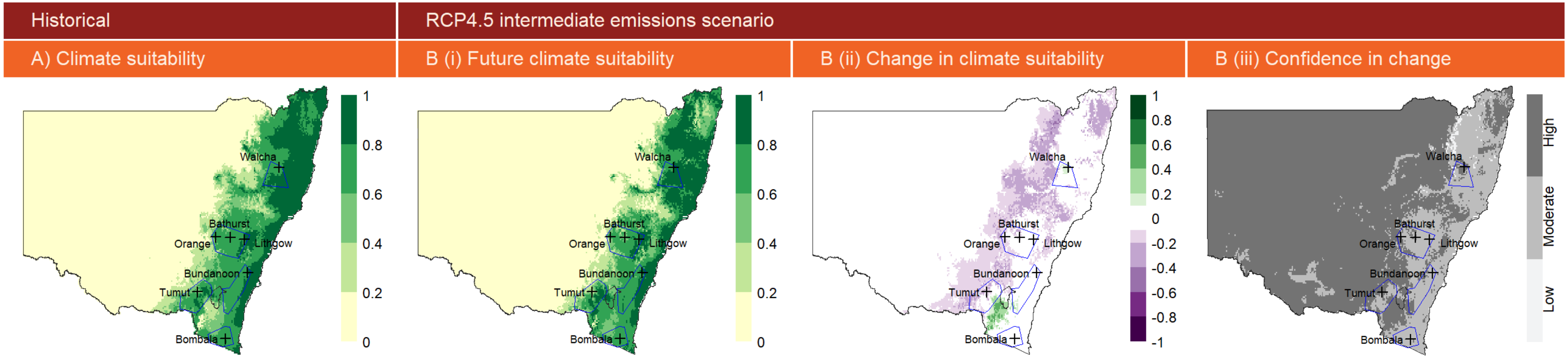


Figure 12: Climate suitability for hot dry conditions during summer for the Radiata pine seedling growth stage in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) 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 pine is currently grown are indicated by blue polygons.

Radiata pine – juvenile



Findings: The juvenile growth stage is likely to be impacted by climate change. Minimal to moderate negative change on the fringes of most growing regions is likely under both emissions scenarios *(moderate to high confidence).*

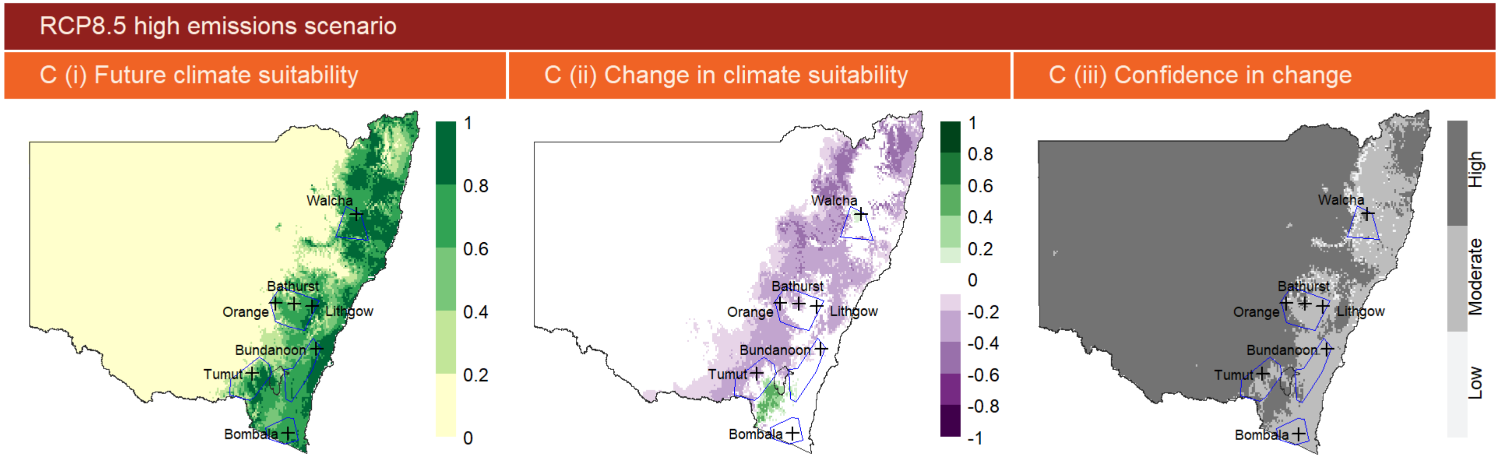
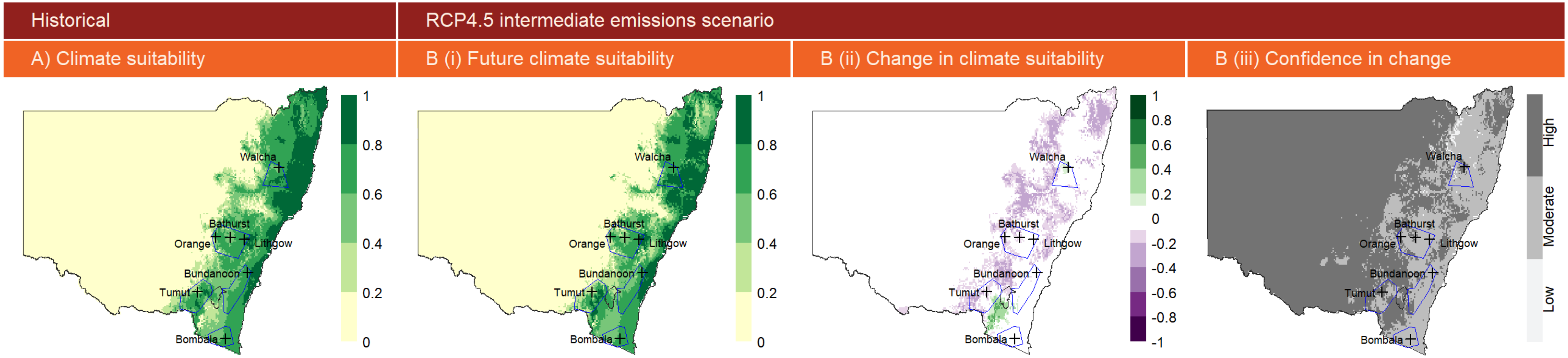


Figure 13: Climate suitability for Radiata pine juvenile growth stage in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows 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 pine is currently grown are indicated by blue polygons.

Radiata pine – adolescent



Findings: The adolescent growth stage is sensitive to the future climate change due to competition for water and other resources including light. Minimal to moderate negative change fringing most growing regions is likely under both emissions scenarios *(moderate to high confidence).*

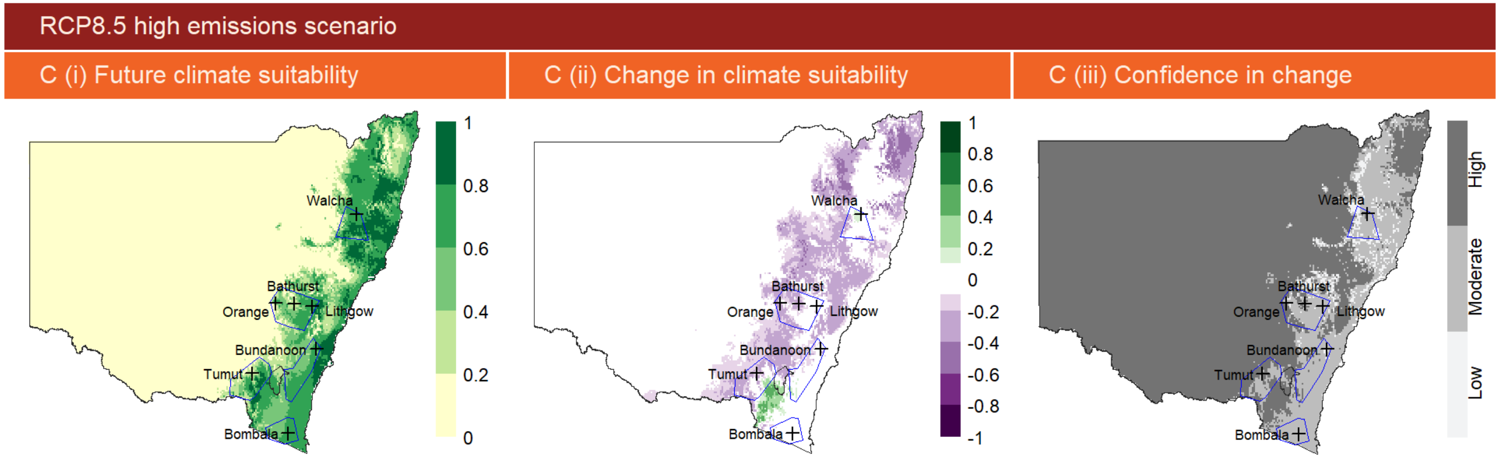
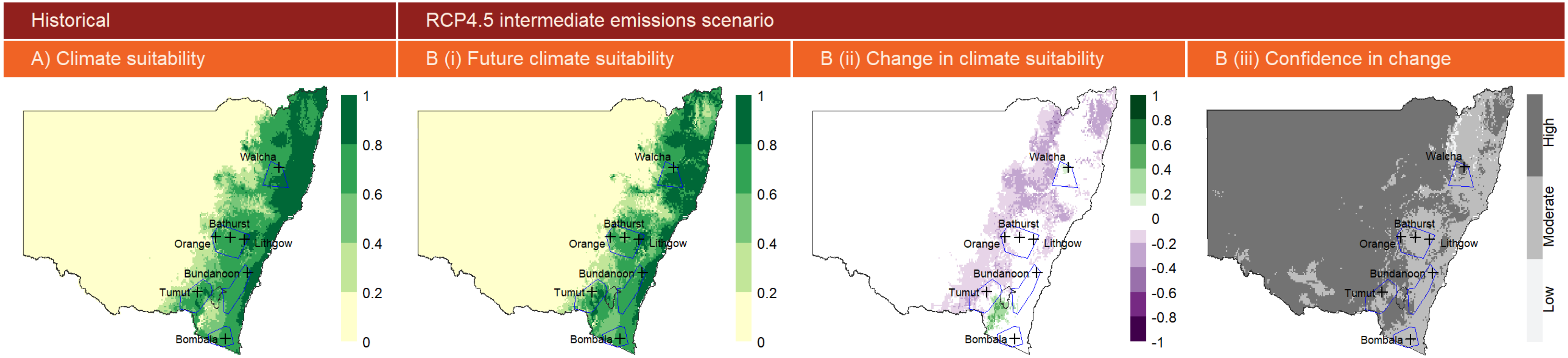


Figure 14: Climate suitability for Radiata pine adolescent growth stage in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) 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 pine is currently grown are indicated by blue polygons.

Radiata pine – mature



Findings: Though less sensitive to the impacts of climate change compared to other growth stages, the mature growth stage is likely to be impacted by future climate change in 2050. Minimal to moderate negative change on the western side of existing plantation areas is likely under both emissions scenarios *(moderate to high confidence).*

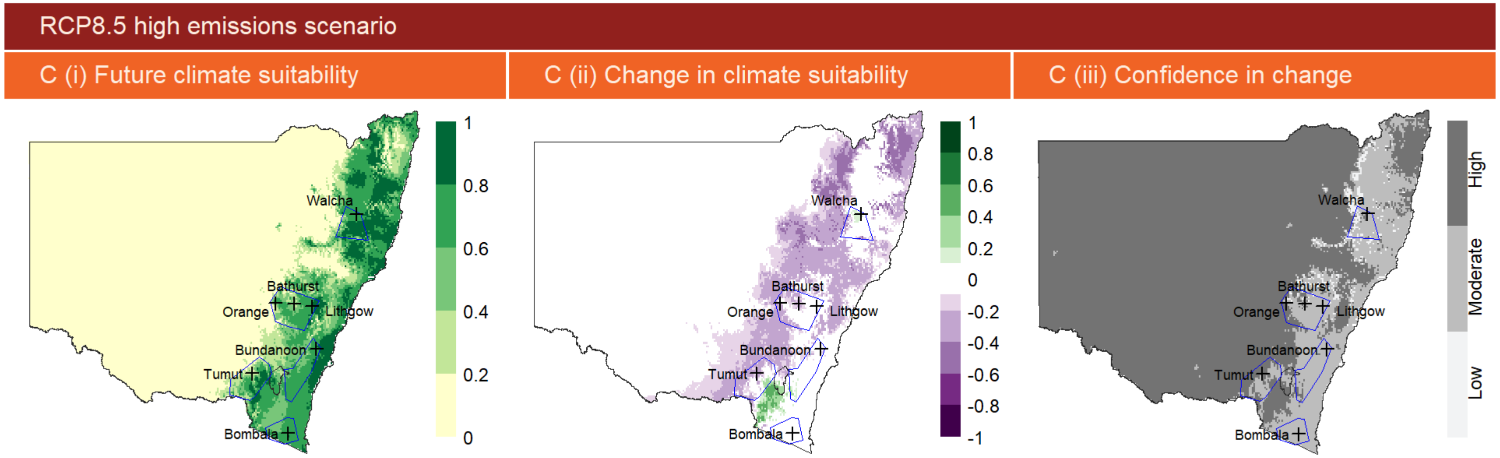


Figure 15: Climate suitability for Radiata pine mature growth stage in NSW. The figure is comprised of 7 maps: A) shows historic climate suitability; B) and C) show future climate suitability for the intermediate and high emissions scenarios, respectively; i) shows future climate suitability, ii) shows 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 pine is currently grown are indicated by 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 Radiata pine, with implications for forestry.

Historical and future trends

Historically climate has been most suitable for pine along the Great Dividing Range and current growing regions have enjoyed moderate to very high climate suitability. Climate change may challenge Radiata pine production in NSW, with some areas expected to decrease in climate suitability for establishing seedlings and thus continued production and during some seasons more than others.

Future climate vulnerabilities

An increased prevalence of hot days, as well as the combination of generally hot and dry conditions in summer (and, to a lesser extent, autumn and spring), is likely to negatively impact climate suitability in the western reaches of the Walcha, Bathurst and Tumut growing regions (*high confidence*). Expansion into areas west of the current growing regions is also likely to be hampered by these changes (*high confidence*).

Future climate opportunities

Reduced prevalence of very cold temperatures during winter under future climates is likely to reduce the frost-induced seedling mortality (*high confidence).* In the future, forest managers could consider expanding plantations to areas previously considered too cold. Looking at the individual growth stages and seasons provides a more nuanced picture of potential changes.

Future fire risk to Radiata pine

Although the Forest Fire Danger Index (FFDI) is commonly provided in future climate projection datasets, this is usually a coarse estimate.

Fuel load, humidity and wind speed are key parameters in assessment of forest fire risk. Wind is highly variable in both space and time, and future projections of wind conditions are unreliable. Creating reliable future projections of FFDI requires sophisticated methods which were outside the scope of this project.

Instead, the Radiata pine MCA model assesses fire risk by considering average seasonal temperatures and rainfall conditions. Vegetation dryness is used as a proxy for fuel load, and this is captured by measuring rainfall over a six-month period including the season of interest and the previous season. In our modelling we assume that the hotter and drier conditions are, the higher the likelihood of forest fire.

Because this combination of high temperatures and low moisture availability also causes stress in trees, the model captures fire risk and moisture stress using the same mechanism – see Appendix 1 for details of the temperature-rainfall matrices employed by the model. Note: that high temperature, low rainfall conditions receive a climate suitability rating of zero in spring, summer and autumn for all growth stages.

Adapting to the changing climate

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

Forest managers could investigate strategies such as:

- ripping, mulching and/or mounding to increase soil water availability,
- minimising competition for soil water and light resources by ensuring adequate weed control,
- optimising spacing of seedlings at planting to increase the volume of soil available for soil water extraction, and
- altering timing of thinning to reduce intra-stand competition.

In the medium term, developing a genetics program could help maintain NSW's Radiata pine production. Such a program could aim to produce trees that can better tolerate expected hotter and drier conditions whilst optimising production (growth). Other tree species more tolerant of the anticipated trend in future conditions could also be considered. A consideration could also be given to different silvicultural regimes such as short rotation woody crops. However, these must be thoroughly researched and tested for the NSW context.

Radiata pine: where to from here?

Future priorities

We have assessed the future climate suitability for Radiata pine as it is a prerequisite for making effective planning decisions and developing adaptation strategies to address future climate change impacts for these long lived trees.

The results presented in this report have identified changes in climate suitability for Radiata pine that will likely have a considerable impact on the NSW industry. More research is needed to best advise the industry on planning future radiata pine rotations, their management (silviculture) and locations where they are planted. 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 cost and disruption to the industry. The following options merit early consideration:

- Genetics program to select more drought and heat-tolerant varieties.
- Assessing the extent to which silvicultural practices such as ripping and/or mounding to increase soil water availability, spacing of seedlings at planting, and timing of thinning could help to manage hotter and drier conditions in future.
- Consideration of the type of product sought and therefore the species, planting configuration, timing and silviculture to enhance survival and growth.

Addressing the gaps, barriers and challenges

The new information generated by this project has helped identify climate vulnerabilities of Radiata pine. 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, these gaps led to the exclusion of key climate criteria because there was a lack of data to justify their inclusion in the model. The following issues were challenging for this model:

- Lack of research on the upper temperature tolerances of the seedling growth stage. Studies of mortality are typically focused on older trees, and modifications made to the parameters for the seedling growth stage were based on expert judgement.
- Tree responses to extreme heat are most apparent during multiple consecutive days of hot conditions. There is a general lack of data in the research literature describing what temperatures, and for how long, cause mortality.

This report aims to highlight these gaps to assist in directing future research and project development. It was not possible to cover all forestry species important to the NSW industry, and so consideration should be given to modelling other significant or emerging forestry species, particularly native forest hardwoods. There is a growing demand for both softwood and hardwood timber and wood products. We suggest expanding the range of the current modelling extent to an Australia-wide basis to inform future industry planning on a national scale.

Conclusion

The Climate Vulnerability Assessment provides important baseline information to support state, regional and strategic industry-level planning for future climate change, highlighting where adaptation and investment should be prioritised to sustain and enhance Forestry in NSW and limit the impacts of climate change on Radiata pine.

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. This research also sets out the challenges ahead, which will require investment in adaptation strategies and new genetics to underpin the softwood forestry industry's future growth and sustainability.

NSW DPIRD will use these findings to work 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.

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 Radiata pine.

Contact us

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

Acknowledgements

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

Thanks to all the NSW Department of Primary Industries and Regional Development staff who participated in the NSW DPIRD Forestry Team: Brendan George, Christine Stone, John Samuel and Samara Booth.

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

NSW
GOVERNMENT

Appendix

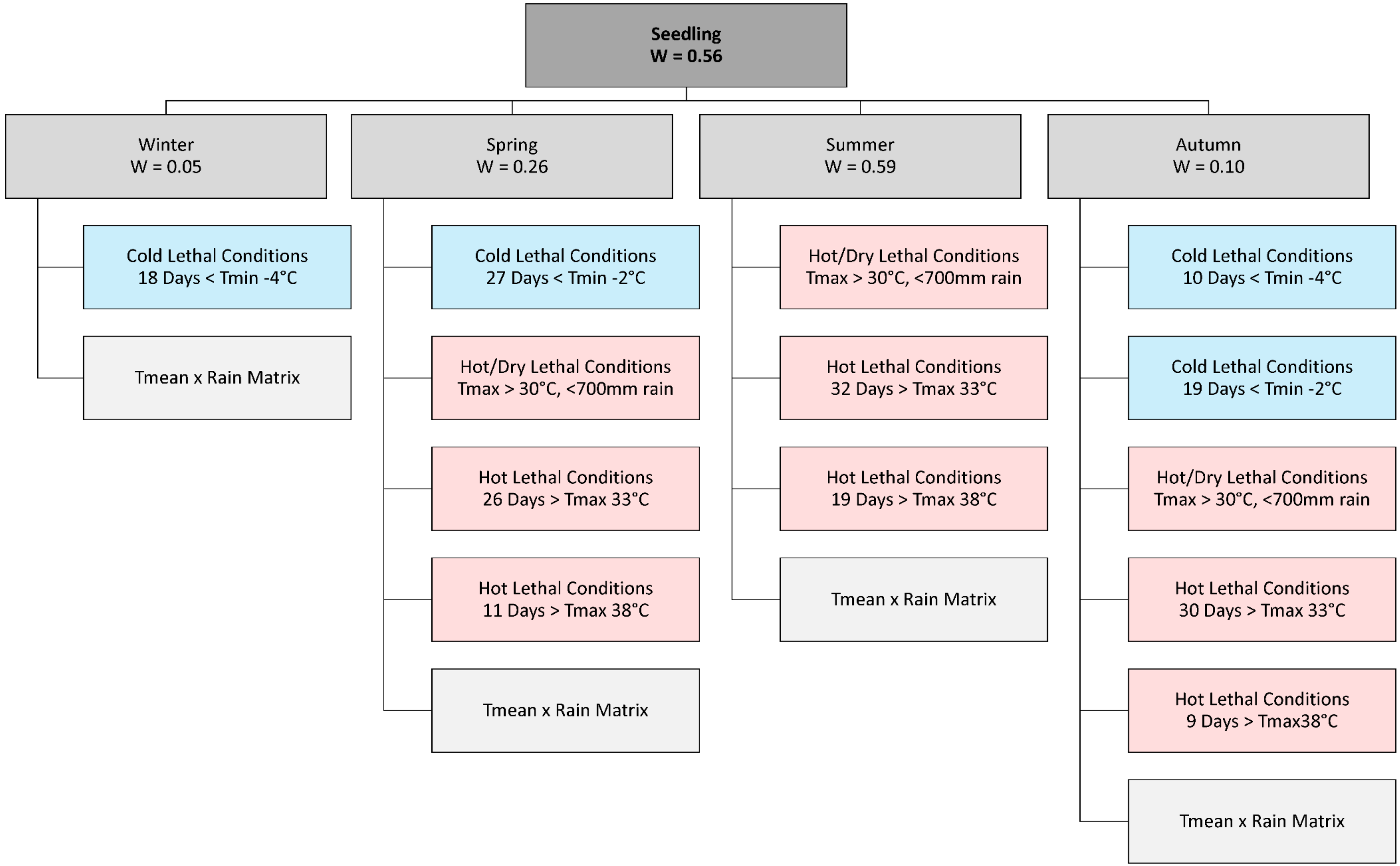


Figure A1: Detailed structure of the seedling growth stage MCA components.

Table A2: Full details of each matrix for the seedling growth stage.

Seedlings: Winter Tmean x Rain Matrix				
		Rain (mm): Autumn + Winter		
		< 250	250 to 500	> 500
Tmean (°C)	< 3°C	R = 0	R = 0	R = 0
	3 to 10°C	R = 0.4	R = 0.6	R = 0.7
	> 10°C	R = 0.2	R = 0.7	R = 1

Seedlings: Summer Tmean x Rain Matrix				
		Rain (mm): Spring + Summer		
		< 250	250 to 500	>500
Tmean (°C)	< 12	R = 0.2	R = 0.4	R = 0.7
	12 to 25	R = 0.3	R = 0.8	R = 1
	> 25	R = 0	R = 0.3	R = 0.5

Seedlings: Spring Tmean x Rain Matrix				
		Rain (mm): Winter + Spring		
		< 250	250 to 500	>500
Tmean (°C)	< 5	R = 0	R = 0	R = 0
	5 to 15	R = 0.3	R = 0.8	R = 0.8
	> 15	R = 0	R = 0.7	R = 1

Seedlings: Autumn Tmean x Rain Matrix				
		Rain (mm): Summer + Autumn		
		< 250	250 to 500	>500
Tmean (°C)	< 5	R = 0.2	R = 0.4	R = 0.7
	5 to 15	R = 0.3	R = 0.8	R = 1
	> 15	R = 0	R = 0.5	R = 0.7

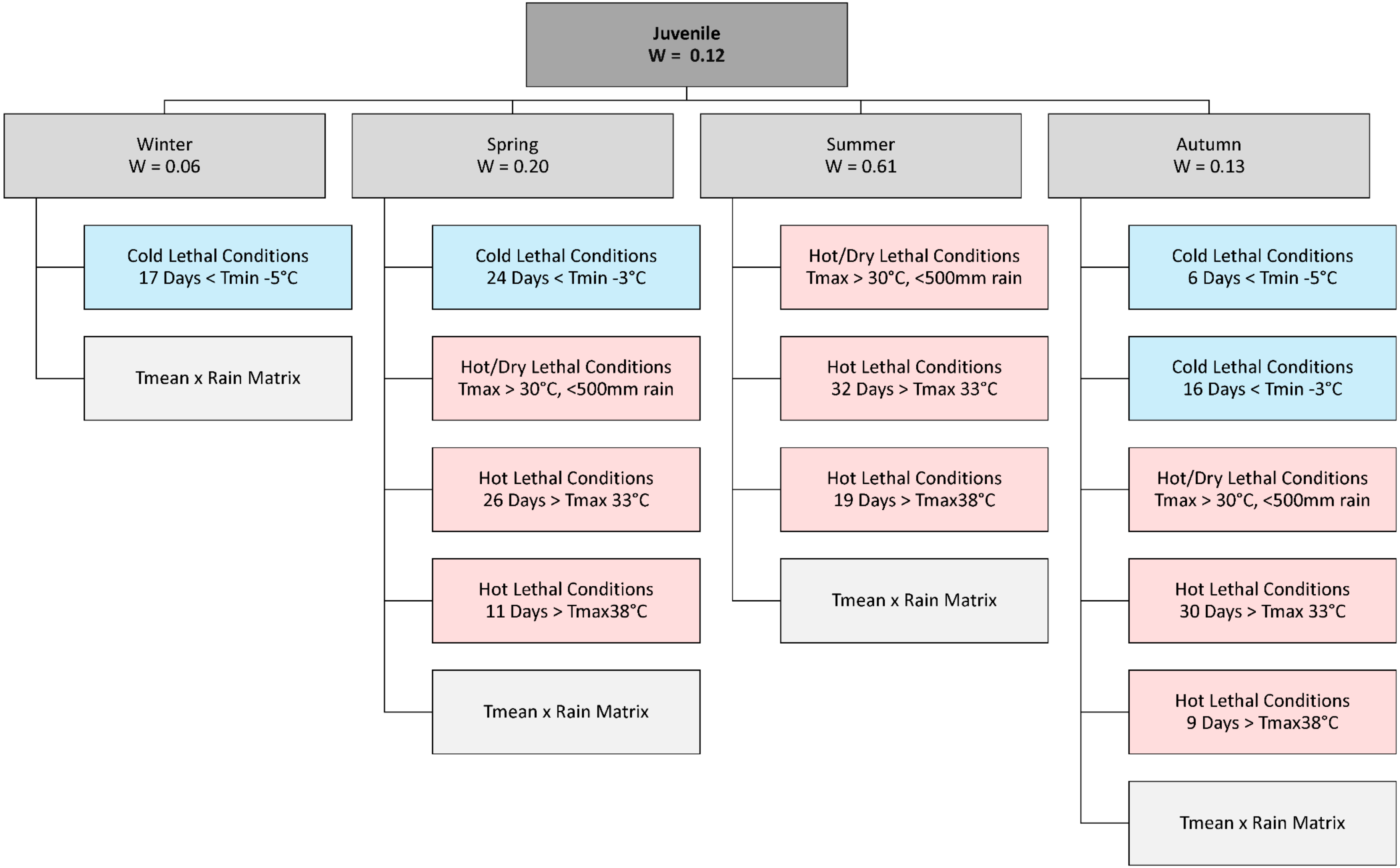


Figure A3: Detailed structure of the juvenile growth stage MCA components.

Table A4: Full details of each matrix for the juvenile growth stage.

Juvenile: Winter Tmean x Rain Matrix				
		Rain (mm): Autumn + Winter		
		< 250	250 to 500	> 500
Tmean (°C)	< 3	R = 0	R = 0	R = 0
	3 to 10	R = 0.4	R = 0.6	R = 0.6
	> 10	R = 0.2	R = 0.9	R = 1

Juvenile: Summer Tmean x Rain Matrix				
		Rain (mm): Spring + Summer		
		< 250	250 to 500	> 500
Tmean (°C)	< 12	R = 0.2	R = 0.5	R = 0.7
	12 to 25	R = 0.3	R = 0.8	R = 1
	> 25	R = 0	R = 0.3	R = 0.5

Juvenile: Spring Tmean x Rain Matrix				
		Rain (mm): Winter + Spring		
		< 250	250 to 500	> 500
Tmean (°C)	< 5	R = 0	R = 0	R = 0
	5 to 15	R = 0.3	R = 0.8	R = 0.8
	> 15	R = 0	R = 0.6	R = 1

Juvenile: Autumn Tmean x Rain Matrix				
		Rain (mm): Summer + Autumn		
		< 250	250 to 500	> 500
Tmean (°C)	< 5	R = 0	R = 0	R = 0
	5 to 15	R = 0.3	R = 0.6	R = 0.8
	> 15	R = 0	R = 0.7	R = 1

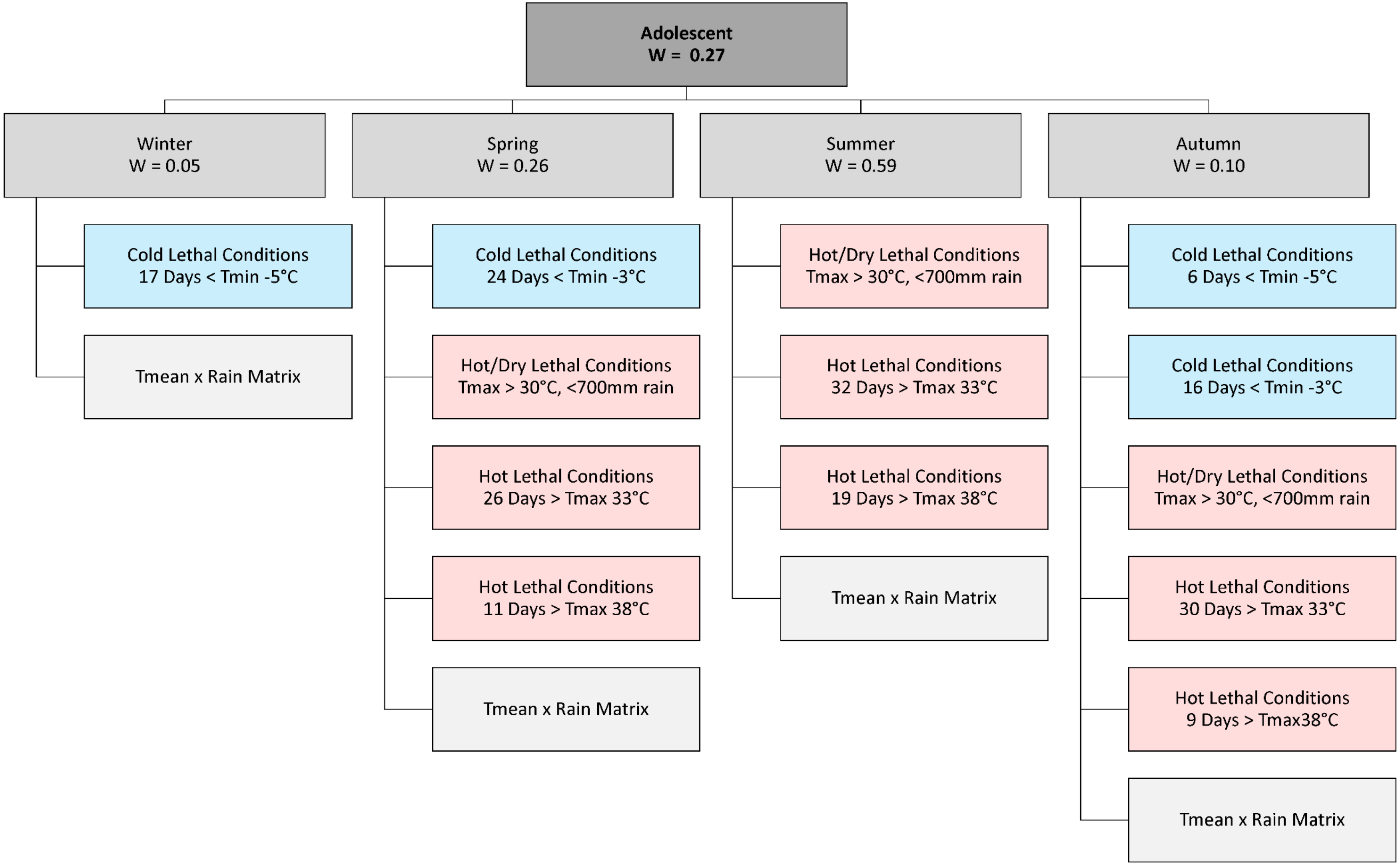


Figure A5: Detailed structure of the adolescent growth stage MCA components.

Table A6: Full details of each matrix for the adolescent growth stage.

Adolescent: Winter Tmean x Rain Matrix				
		Rain (mm): Autumn + Winter		
		< 250	250 to 500	> 500
Tmean (°C)	< 3	R = 0	R = 0	R = 0
	3 to 10	R = 0.4	R = 0.6	R = 0.6
	> 10	R = 0.2	R = 0.9	R = 1

Adolescent: Summer Tmean x Rain Matrix				
		Rain (mm): Spring + Summer		
		< 250	250 to 500	> 500
Tmean (°C)	< 12	R = 0.2	R = 0.5	R = 0.7
	12 to 25	R = 0.2	R = 0.7	R = 1
	> 25	R = 0	R = 0.4	R = 0.5

Adolescent: Spring Tmean x Rain Matrix				
		Rain (mm): Winter + Spring		
		< 250	250 to 500	> 500
Tmean (°C)	< 5	R = 0	R = 0	R = 0
	5 to 15	R = 0.3	R = 0.6	R = 0.8
	> 15	R = 0	R = 0.6	R = 1

Adolescent: Autumn Tmean x Rain Matrix				
		Rain (mm): Summer + Autumn		
		< 250	250 to 500	> 500
Tmean (°C)	< 5	R = 0	R = 0	R = 0
	5 to 15	R = 0.1	R = 0.5	R = 0.7
	> 15	R = 0	R = 0.6	R = 1

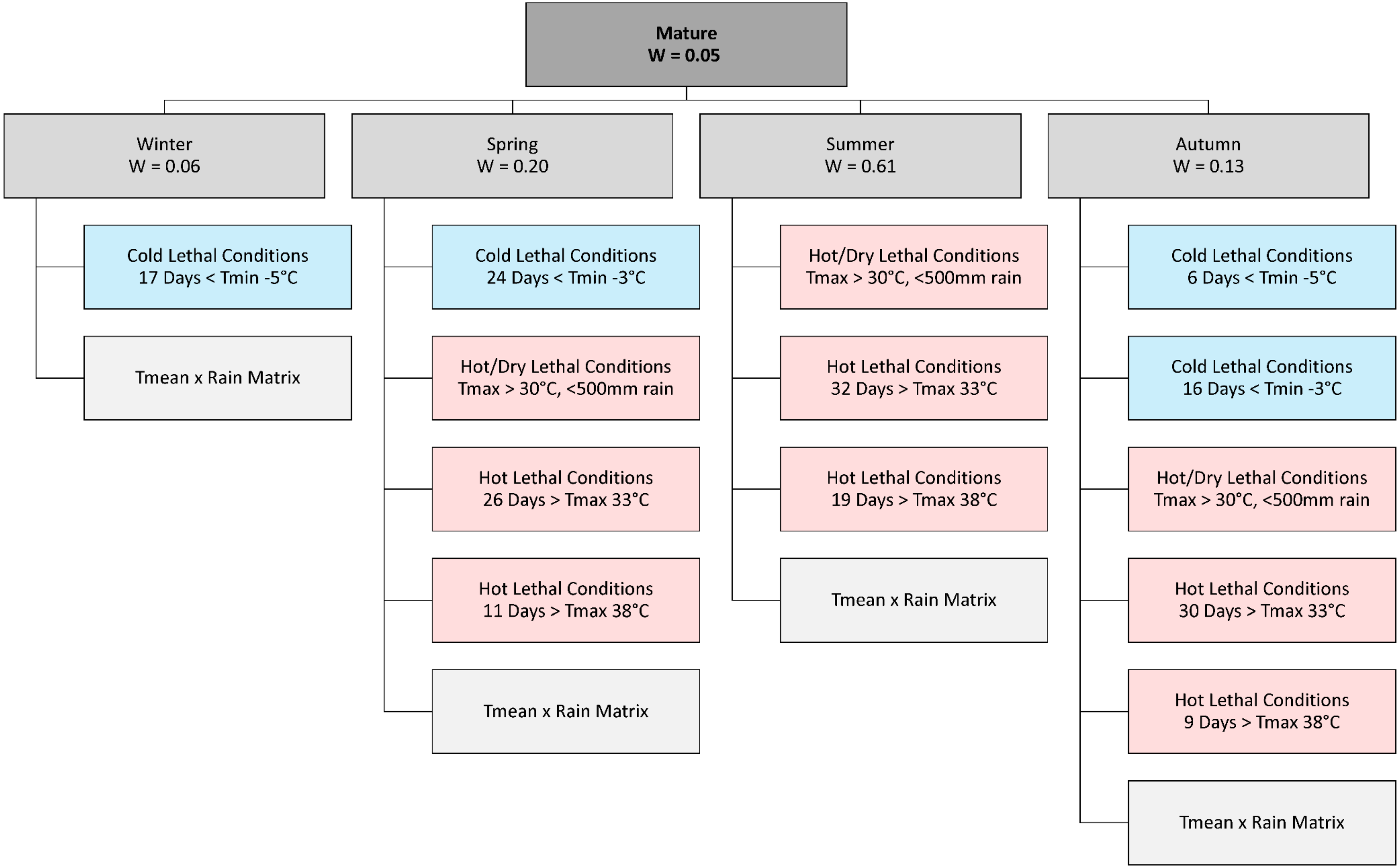


Figure A7: Detailed structure of the mature growth stage MCA components.

Table A8: Full details of each matrix for the mature growth stage.

Mature: Winter Tmean x Rain Matrix				
		Rain (mm): Autumn + Winter		
		< 250	250 to 500	> 500
Tmean (ºC)	< 3	R = 0	R = 0	R = 0
	3 to 10	R = 0.3	R = 0.6	R = 0.7
	> 10	R = 0.3	R = 0.9	R = 1

Mature: Summer Tmean x Rain Matrix				
		Rain (mm): Spring + Summer		
		< 250	250 to 500	>500
Tmean (ºC)	< 12	R = 0.3	R = 0.6	R = 0.7
	12 to 25	R = 0.2	R = 0.8	R = 1
	> 25	R = 0	R = 0.3	R = 0.4

Mature: Spring Tmean x Rain Matrix				
		Rain (mm): Winter + Spring		
		< 250	250 to 500	> 500
Tmean (ºC)	< 5	R = 0	R = 0	R = 0
	5 to 15	R = 0.3	R = 0.7	R = 0.7
	> 15	R = 0	R = 0.6	R = 1

Mature: Autumn Tmean x Rain Matrix				
		Rain (mm): Summer + Autumn		
		< 250	250 to 500	> 500
Tmean (ºC)	< 5	R = 0	R = 0	R = 0
	5 to 15	R = 0.1	R = 0.5	R = 0.7
	> 15	R = 0	R = 0.5	R = 1

Primary Industries Climate Change Research Strategy

Climate Vulnerability Assessment

Radiata Pine Results Report

NSW
GOVERNMENT