CLIMATE–READY REVEGETATION IN THE YASS AREA NETWORK LANDCARE REGION

Full report

Yass Area Network of Landcare Groups (YAN)
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Acknowledgements

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The development and implementation of this project has been guided by a core team of Landcare members who are authors of this report. Funding to support the Climate Ready Action Planning Workshop in 2018 which initiated this project was made available by the NSW Office of Environment and Heritage. The Department of Industry and Environment has provided ad-hoc support of climate specialists to work with the YAN Climate Ready Revegetation team throughout the project. Purchase of seed for the initial trial was partly funded by: NSW Office of Environment and Heritage, South East Local Land Services, and a Michael King Grant via Landcare Australia. From 2021-22, the YAN Landcare Groups and further Michael King Grants have contributed to the ongoing purchase of seed with admixture provenance to grow plants for Landcare's nurseries and revegetation projects.

Completion of the first stages of the project has also been made possible by the support of YAN and the commitment of a substantial portion of the YAN Coordinator's time in since 2019.

Several other projects within YAN are also linked to this Climate Ready Re-vegetation Project. Other working groups and projects that have links to this project, include the Nursery Manager's Group, Seed Collectors Group, Let's Try It Project, Yass Paddock Tree Project, and Habitat Hops from Burrinjuck to Bango Project.

Detailed results and methods can be requested by emailing to YAN's Climate Ready Revegetation project officer climateready@yan.org.au.

CONTENTS

APPENDICES

INTRODUCTION AND RATIONALE FOR THE PROJECT

Background

The climate is changing rapidly due to increasing greenhouse gas emissions, and the resultant global warming threatens the survival of many species, including plants. This project is focussed on the ability of plants to survive in the Yass region in the face of these future changes. While accepting the continuing importance of other factors in the environment that may impact on a species ability to survive, such as land use changes and habitat fragmentation, it is expected that climate change will have an over-riding additional impact.

In an attempt to devise a method to assist nurseries and others to help populations of plants to withstand this rapid change, a publication has been produced by Hancock et al. (2018) called *Climate-ready Revegetation Guide*. The publication outlines a method thought likely to enhance plant species' survival into the future when conditions are expected to be hotter, more variable, and less predictable.

The Climate-ready Revegetation Guide (Hancock et al., 2018) provides the means for land managers and plant nurseries to analyse which plants will be best suited to the projected climate, and where to source seed. It includes methods to find out the projections of localised climate change, the current distribution of different species, and how to overlay the distribution and projected climate models to determine a suitable seed sourcing strategy. Nola Hancock and Linda Broadhurst described the rationale for the Guide as follows:

> The information in the Guide is based on the premise that survival and resilience will be enhanced for species and local populations with large, genetically diverse populations. Species differ in their vulnerability to climate change. Species that cannot evolve and adapt to new environmental conditions in-situ as fast as the climate changes, or disperse to more suitable climes, will be more vulnerable than those with the evolutionary potential and/or the capacity to disperse. In theory, plants with wide distributions are more likely to cope with climate change than those with narrow distributions. However, even if a species' distribution indicates that it is able to tolerate a broad range of climate conditions, survival of local populations are not guaranteed (Hancock & Broadhurst, 2018).

Revegetation is an activity prioritised by Landcare, a volunteer organisation that extends throughout much of Australia. Members are brought together by a common interest to *Care for Land,* and a number of groups have nurseries that grow plants suitable for revegetation and undertake revegetation projects. In the Yass Valley region at the time of writing there are four active Landcare groups (Bowning-Bookham, Murrumbateman, Sutton and Yass) under the umbrella of the Yass Area Network of Landcare Groups (YAN), and there are four community nurseries that grow local native species. Seed for growing tubestock has mostly been sourced from local vendors (primarily Greening Australia), but the application of the climate-ready species selection requires sourcing seed from commercial suppliers from more widespread regions.

In the future, the Landcare networks could conceivably provide a starting point for collaborations for sourcing seed across wider areas, especially if the Landcare groups also collected seed from their own regions.

This report outlines how the methods in the Revegetation Guide (Hancock et al., 2018) is being applied by Landcare and other stakeholders in the Yass Valley region. Our intention is that by adopting a 'climate-ready' strategy, we aim to improve the chances of planted species surviving into the future through judicious selection of seed to increase genetic diversity and the health and viability of local ecosystems. Additionally, by trialling the application of the Guide in the Yass Valley region, we hope to develop a model able to be used in other regions.

Aim

The aim of the project is to assist the long-term survival of native plants in the Yass Valley region of NSW under changing climatic conditions, through judicious selection of seed provenance to enhance genetic diversity.

There are five parts to the project to achieve this aim, described more fully in the remainder of this report:

1. Understand our local climate, both current and projected, and develop an appropriate seed-sourcing strategy;
2. Identify plant species likely to tolerate climate change in our area. Initially this will comprise a limited number of local species. Later, the possibility of incorporating suitable species not currently growing in the Yass region may be explored;
3. Obtain seed for these species from suitable provenances as identified from the projected future climate;
4. Incorporate 'climate ready' seed collections into nursery seed stocks;
5. Run a small trial to assess whether there is variation in survival of plants from local versus non-local admixture provenances, across a limited number of different species.

PART 1: UNDERSTAND OUR LOCAL CLIMATE, BOTH CURRENT AND PROJECTED, AND DEVELOP AN APPROPRIATE SEED SOURCING STRATEGY

Before beginning analysis of individual species and provenances it was important to develop an understanding of the current local climate and the projected future climate in the Yass region, and to develop a seed-sourcing strategy.

Current climate

The project covers the YAN region, which has a known climate gradient between Canberra (coolest) and districts further north including Sutton, and further west to Bookham (hottest). The current gradient, based on data from the recent past for temperature and rainfall across the YAN region is shown below in Table 1. This shows fairly similar rainfalls but a gradient of about one-degree Celsius annual average temperature increasing across the region from Canberra to further west (data collated from BOM by YAN team).

The data used in Table 1 are from the closest relevant weather stations to Yass – Murrumbateman, Sutton and Bookham – for which data were available in the recent past (in the period around 1960 to 1990). Note that some variation may occur between this table and weather data presented in subsequent tables depending on the time period and actual weather stations used in collating data, or whether the figures are derived from modelling.

Table 1: Historical climate characteristics across the YAN region (1961-1990)

	Temperature	Rainfall						
Location (BOM stn in brackets)	**Annual Range (Average Min-Average Max)**	**Absolute Min**	**Absolute Max**	**Days Frost (average <0°C)**	**Annual Rainfall (average)**	**Absolute Min Annual**	**Absolute Max Annual**	**Days Rain >1mm (average)**
Sutton (CBR Airport)	6.5-19.6°C	-10.0°C	42.2°C	63 days	623.2mm	262mm	977mm	74 days
Bookham (Harden)	7.5-21.8°C	-7.5°C	41.8°C	46 days	611mm	299.6mm	876mm	76 days
Yass and Murrumbateman (Yass)	7.0-20.5°C	-8.8°C	41.2°C	46 days	681.6mm	285mm	983mm	79 days

Source: Bureau of Meteorology. For more detail see footnote.[1]

It is also worth noting that there is considerable variation within the Yass region depending on topography. For example, Burrinjuck weather station, situated near the Murrumbidgee River and close to hills, has recorded considerably more rain than other stations in the region (annually 957mm average, with 409 mm minimum and 1441mm maximum, and an average of 91 days rain each year).

The average annual Yass temperature can be approximately calculated by taking the midpoint between the annual minimum (7°C) and annual maximum (20.5°C) temperatures from the table, which is approximately 14°C.

Projected Climate

Initially we used projections for the whole south east of NSW, aligning with the region considered in the government Snapshot publication on Climate Change for South East and Tablelands (NSW Office of Environment and Heritage, 2014). However, the wide range of different landscapes made this problematic as the south east region includes alpine areas, coastal areas and slopes. Each of these landscapes has a different climate leading to very wide projections when considered together. We therefore limited projections to a much smaller region involving a 40 km radius centred on Yass (approximation shown in Figure 1) to improve the relevance of the analysis. This was found to be much more useful for assessing likely plant tolerance in this project.

[1] BOM Climate Data, 1 Jan 1961 to 31 Dec 1990 or closest available. Monthly Main Statistics Report. Sites:

- Sutton (Canberra Airport), 1960-1990 temperatures and rainfall, BOM site 070014, 35.3°S 149.2°E, elevation 578m;
- Bookham (Harden, East St), 1967-1980 temperatures, 1960-1980 rainfall, BOM site 073016, 34.6°S 148.4°E, elevation 430m;
- Yass /Murrumbateman (Yass, Linton hostel), 1965-1990 temperatures, 1960-1990 rainfall, BOM site 070091, 34.83°S, 148.91°E, elevation 520m;
- Burrinjuck Dam, BOM site 073007, 35.0°S 148.6°E, elevation 390m.

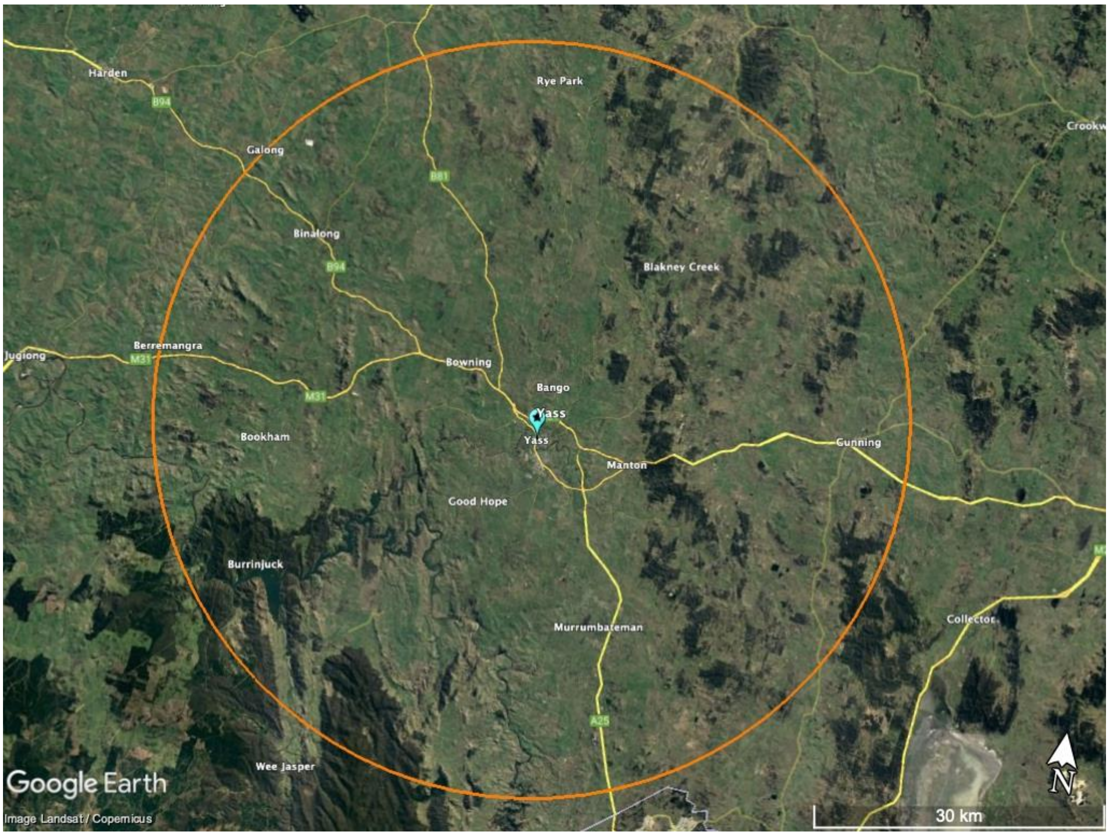


Figure 1: Approximate Area of Yass +40km Zone

In this study, projections for Yass +40km radius, were obtained for temperature and rainfall. This included annual average temperature and annual average total rainfall. Initially data were also aggregated at a monthly level but this was found to be less useful than data aggregated at a quarterly (3 month) level for the hottest quarter, the driest quarter, the coldest quarter and the wettest quarter.

The aim of these projections was to compare them with the equivalent current 'climate envelope' variables for each species investigated. The current quarterly variables give some insight into how a species copes with seasonal variation, and when compared with Yass region projections whether it is likely to tolerate the projected hottest quarter, driest quarter, coldest quarter, and wettest quarter.

The projections are from NSW and Australian Regional Climate Modelling (NARCliM) data, provided by Department of Primary Industries and Environment officers in 2019 (Isobel Cummings and Polly Mitchell). The climate projections are from 12 different models used in NARCliM data – some details that indicate the complexity of the modelling are shown in Box 1 below. The resultant figures from the modelling are shown in Figure 2 and the data produced by the models are in Appendix 1.

Box 1: Some Characteristics of Modelling of Projected Climate

Dynamical downscaling of GCM projections – 12 ensembles:
4 GCMs (MIROC, ECHAM, CCCMA, CSIRO mk3.0) – IPCC CMIP3 models
3 RCMs (WRF with different physics – PBL, cumulus, radiation)
A2 emission scenario (comparable to AR5 RCP8.5)

Periods modelled:
3 Epochs - 1990-2009 (base case); 2020-2039; 2060-2079
Reanalysis simulations (1950-2009) – NCEP data into RCMs

Source: Hancock, Mitchell & Cummings 2019.

Climate projections are based on likely carbon emission scenarios. As shown in Box 1 above, in this case, they were based on the "A2" CO_2 scenario from the 4th report of the International Panel on Climate Change (IPCC 2007).[2] This scenario may be somewhat more conservative than the later 5th report 'RCP 8.5' version (IPCC 2014), but both represent higher emission pathways. The higher end scenario was used in the modelling as it is the closest to the actual emission pathway the world is tracking along. Current global emissions amount to around 50 billion tonnes of CO_2-equivalent each year, an increase from around 35 billion tonnes of CO_2-equivalent each year in 1990 (Ritchie & Roser 2020).

Yass region climate projections (from the 12 NARCliM selected climate models) are across the geographical landscape of a selected polygon – a 40km radius polygon starting from a decimal latitude and longitude for Yass of approximately 34.85°S, 148.9°E. The *average of the 12 medians* from the projections from the 12 climate models are shown in the table below, for annual and quarterly climate data (NARClim data via DPIE, averaged by YAN). A 'quarter' is a 12 week period – the quarters are the hottest 12 weeks, the driest 12 weeks, the coldest 12 weeks and the wettest 12 weeks. The projections are for 2030 and 2070 respectively. The current Yass values are WorldClim data and may vary slightly from BOM data.

It is important to note that the data in the table do not display the uncertainty inherent in the projections and are given as a simple guide only, for ease of interpretation. Please read more details about uncertainty given below and the variation in the model outputs can be seen in Appendix 1.

[2] Further explanation of this can be found here: https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/About-NARCliM/Emissions-scenarios

Table 2: Average* Climate Projections for the Yass Region

ANNUAL	CURRENT	2030 PROJECTION	2070 PROJECTION
Annual temp (°C)	13.6	**14.6**	**15.9**
Annual rain (mm)	706	**655**	**674**
QUARTERLY			
Hottest quarter av temp (°C)	20.2	**21.8**	**23.3**
Coldest quarter av temp (°C)	6.5	**7.6**	**8.7**
Driest quarter rain (mm)	167	**120**	**121**
Wettest quarter rain (mm)	213	**204**	**210**

*Showing the *average of the 12 medians* from the projections from the 12 NARCliM climate models. Current Yass is Worldclim data (note that Worldclim data vary somewhat from the BOM recent historical data).

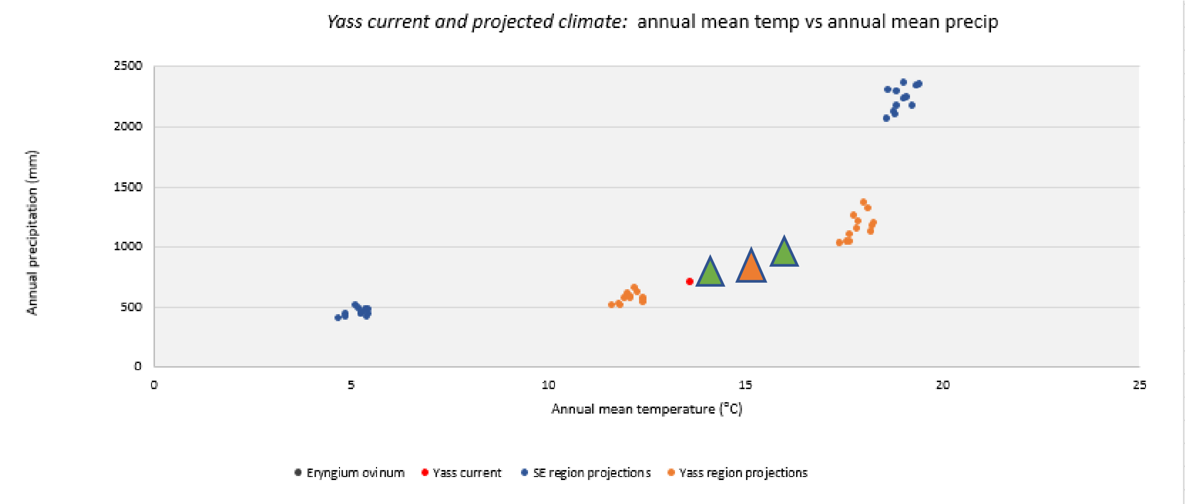
Table 2 shows that by 2070, the projected 'average' annual temperature for the Yass region is expected to be around 2 degrees Celsius hotter than the current annual temperature. The projected average annual rainfall is projected to be around 674mm by 2070 compared to the current 706mm. We can note a probable change in the distribution of rain over the year as the projections for the driest quarter are notably less than the current driest quarter.

In fact, each of the projection models produce many estimates, not just one simple number, as detailed in Appendix 1. The highest and lowest estimates give the *range* of projections, and the *median* is in the middle between the lower and upper ends of the range. Due to the uncertainty in the projections, for each of the 12 models described in Box 1, the *range* of 2070 projections are used to assess species' tolerance to climate change, rather than just the simple average of the median shown in the table above.

In Figure 2 below, the climate projection graphs show temperature on the X axis plotted against precipitation on the Y axis. There are 12 brown points for the lower end of each of the modelled projections for 2070 of the temperature and rainfall, and 12 brown points for the upper end of each of the modelled projections. Yass current climate is shown as a red dot. The ranges for the south east region are blue dots. There are three graphs shown below – the first shows annual temperature and rainfall data, the second the temperature and rainfall in the hottest and driest quarters, and the third the coldest vs wettest quarters.

Also, in Figure 2, a brown triangle has been superimposed on the graphs to show the average of the 12 medians from the 12 models, together with the average 5th and 95th centiles of the 12 model estimates shown as green triangles. This group of triangles represents by far the major proportion of estimates from the models (90% of estimates) while the range (between the brown dots) represents the total distribution of estimates from the models. The simplest way to view the graphs is to look at the current Yass climate – the red dot – and look at the projected median temperature and rainfall – the brown triangle (roughly the mid-point between the brown dots). However, it needs to be borne in mind, that the range of projections from the models also suggests the possibility of future temperatures and rainfall that are not simply at the median value. Looking at the range of values is generally considered a more meaningful way to use the projections as it accounts for uncertainty.

1.



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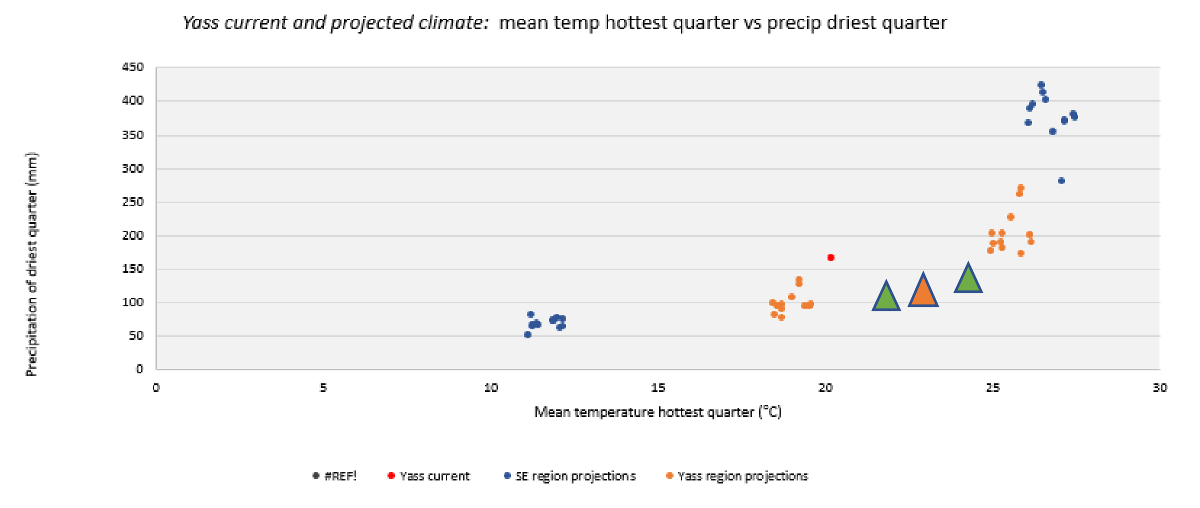

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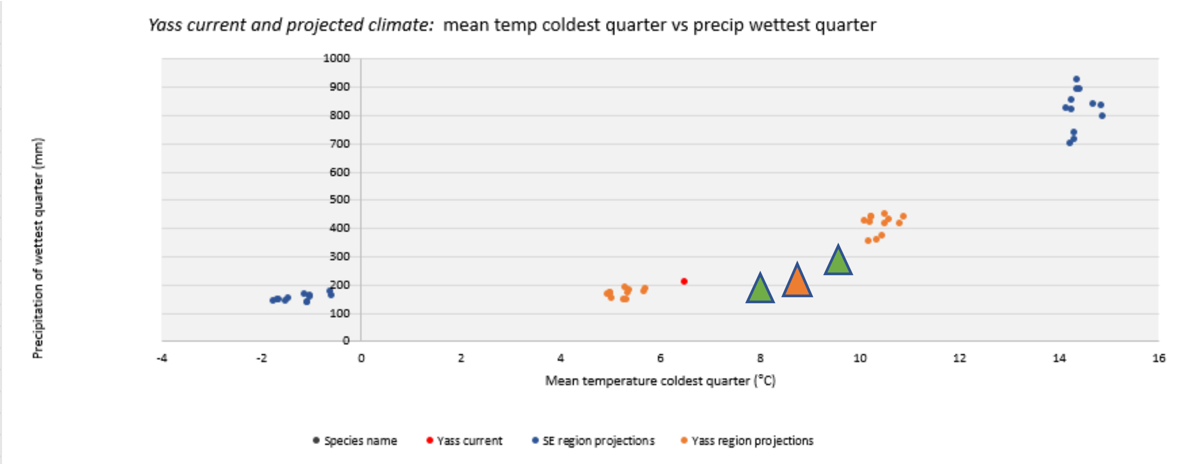


Figure 2: Yass region (and SE region) climate projections 2070 - the range of projections from the 12 models

It can be seen that the group of triangles, where most of the model projected values occur, are always closer to the hotter end of the temperature range, and generally closer to the lower end of the rainfall range. This suggests that when interpreting the range of values in the graphs, we should put greater weight on the importance of the hotter end of the range of temperature projections, and probably more weight on the drier end of the range of rainfall projections. Another reason to focus on the hotter end of the range of projections is that global carbon emissions continue to increase each year and are continuing to progress at the high-end scenarios. It therefore seems that there is a real possibility of reaching temperatures towards the higher end of the projection scenarios, which is approximately 5°C hotter than the current average annual temperature. A deliberate decision was therefore made by the project team to focus especially on the hotter end of the range of projections when assessing a species for tolerance to climate change. Each species was assessed for likely tolerance to (a) hotter/drier climate and (b) hotter/wetter climate.

More details are given about the general south east region projected climate in the South East and Tablelands Climate change snapshot publication produced by the NSW government (NSW Office of Environment and Heritage, 2014). This publication explains that we can expect that rainfall will shift to being summer/autumn predominant, with less rain in spring and winter compared to historical records.

A map showing the approximate equivalent geographic spread of areas in eastern Australia that are currently analogous to the projected climate for Yass+40km was created by the YAN team in order to assist with deciding where to obtain seed. This is discussed in Part 3 and Appendix 3E of this report.

Developing an appropriate seed sourcing strategy

The Climate Ready Revegetation Guide (Hancock et al., 2018) outlines five provenance options for seed sourcing: 1. Climate adjusted; 2. Local; 3. Composite; 4. Admixture or 5. Predicted. Figure 3 shows the difference between the different strategies diagrammatically.

The publication gives guidance for choosing the best option for individual species. However, we concluded that for all species in this project, consistently using the ‘admixture’ option with some bias to ‘climate adjusted’ was our best choice for the reasons outlined below.

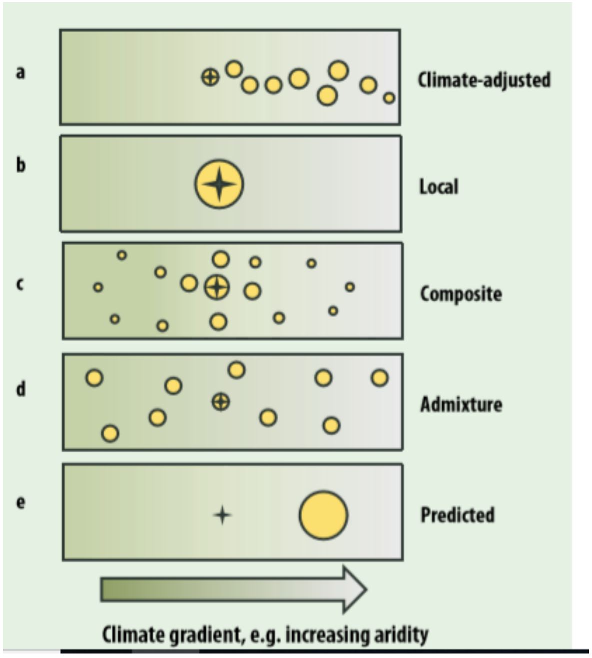


Figure 3: Possible Seed Provenance Strategies

Source: Hancock et al., 2018.

The five alternative strategies proposed for sourcing or collecting seed incorporate varying levels of priority and specificity to anticipated climate change (Prober et al., 2015). Of these, we adopted an 'admixture' selection strategy with some bias towards a 'climate adjusted' approach, for all species selected to be grown in the nurseries.

The admixture strategy aims to build evolutionary resilience into plantings by mixing a wide variety of provenances from sources across a species' range, including local seed sources (Breed et al., 2013). In this project, a condition of selecting a species for admixture seed collection is that it has a range that goes at least part way along a climate gradient of increasing temperature, which is the most reliable projected variable associated with climate change. The projections for rainfall are wide in Yass region, and the admixture strategy is more appropriate when changes in conditions are expected but there is a degree of uncertainty about the specific conditions.

For our network of Landcare groups, the advantages of consistently using the admixture approach for all selected species (with some bias towards sampling 'climate-adjusted' populations), are seen to be:

1) While temperature increase is reliably predicted in climate change scenarios, other weather factors are more uncertain e.g., rainfall amount and seasonality, frost frequency and severity, and waterlogging. Attributes important to the tolerance of these factors may be found in populations across the entire geographic range of a species, and not necessarily represented along the gradient of temperature increase.

2) For an organisation based on volunteerism, it is operationally more practical to apply a single strategy that is not overly demanding in requiring seed from specific sites.

3) It is a sampling strategy that will enable a high priority to be given to seed collected from sites that have large populations (providing a greater likelihood of quality seed) and from which large numbers of individuals can be collected (providing an adequate sample from the available genotypes). In the Yass Valley landscapes, which are heavily fragmented by agriculture, seed quantity and quality is a major limiting factor. There are also strong plant conservation reasons to avoid collecting seeds from small populations.

4) There are elements of environmental variation which may be important to the success of plantings that are unrelated to climate variability. Lithology, soil, landscape position all vary across the landscape and a single species may have populations growing across a range of levels of these and other variables. However, this variation may not be covered in a sampling strategy that follows a simple temperature gradient. Matching of these factors in donor and receiving sites might be preferred, but this is difficult to achieve in a community nursery setting and may not even be the best solution in a changing environment. Admixture sampling will maximise the genetic variation linked to different habitats and potentially increase the long-term success of planted populations.

It was therefore concluded that the admixture approach to seed collection could be followed for all species, with some bias towards climate adjusted. In summary, the advantages of using this one seed collection strategy are:

- It will be simplest for the project to use just one provenancing approach;
- Most assessments of species using the desktop process outlined in Hancock et al. (2018) are likely to lead to an admixture approach;
- An admixture approach should enable the genetic diversity of plantings to be maximised.

PART 2: IDENTIFYING PLANT SPECIES LIKELY TO TOLERATE CLIMATE CHANGE IN OUR AREA

The Climate Ready Revegetation Guide describes how to graphically present the current 'climate envelope' for a species and overlay this with climate projections to assess whether a species may tolerate projected future climate conditions in an area. This process enables both the identification of species that are more likely to tolerate climate change, and subsequent selection of suitable provenance sites for seed sourcing. The method used in this project was adapted from this Guide (Hancock et al., 2018).

The objective for Parts 2 and 3 of this project was to create a list of likely climate change tolerant species suitable for the YAN nurseries to grow, and to obtain admixture seed for these species. The plants grown from this admixture seed would then be used in local revegetation activities and in the project trial (refer to Part 5 later in this report).

After identifying a number of local species likely to tolerate climate change, a narrower selection of species was chosen for the YAN nurseries to grow as described in Part 4. These species occur across a range of habitats in the Yass region. Suitable seed provenances for these species were found by adapting the methods described in the Climate-ready Revegetation Guide (Hancock et al., 2018) as detailed in PART 3: OBTAINING ADMIXTURE SEED FOR SELECTED SPECIES FROM SUITABLE PROVENANCES.

The following section describes how species were assessed for likelihood of tolerating future climate conditions in the Yass Area. A summary table of the results for the first 80 species assessed is provided at the end of this section. Access to the detailed results for each individual species can be requested by emailing the Climate Ready project officer climateready@yan.org.au.

Method: How to assess climate tolerance of local species

The steps used in this project to identify species that are likely to tolerate climate change in the Yass region were to:

i. Compile a nursery species list from the four Landcare nurseries in YAN;
ii. Produce maps of the distribution of current occurrence sites of each of the species across Australia;
iii. Produce 'climate envelope' graphs for each species using annual and quarterly (12 week) data on temperature and rainfall obtained from current occurrence sites;
iv. Overlay the climate envelope graphs with the range of projected climate characteristics (temperature and rainfall) for the area Yass +40km (as shown approximately in Figure 5);
v. Interpret the climate envelope graphs to assess each species as likely to be 'climate change tolerant' or not (i.e. found currently in areas experiencing the projected Yass region climate or not);
vi. Checking the results of species assessment.

Each step is explained below, and how this was done is shown in detail in Appendices 2a, 2b, 2c and 2d.

i) Compile a nursery species list from the four Landcare nurseries in YAN.

It was decided to first investigate species that currently grow in the Yass region rather than looking outside the region for species not currently found in the vicinity. A local species list was compiled from species already being grown in the four YAN Landcare nurseries. This list comprised about 80 species. The species selected for investigation, and the results of assessment are shown at the end of this section.

ii) Produce maps of the distribution of occurrence sites of each of the species across Australia

Maps of the current distribution of occurrence of each species were accessed from the 'Niche Finder' website (NSW Office of Environment and Heritage & Macquarie University). A wider geographic distribution is generally believed to be advantageous for tolerating climate change, especially if it includes hotter regions. A distribution into outback Australia will suggest that the species tolerates hotter and drier climates; a distribution along the coast of Queensland suggests the species tolerates a hotter, wetter climate with high summer rain. An example distribution map of *Eucalyptus melliodora* is shown here. Details about how to make these maps are in Appendix 2A.

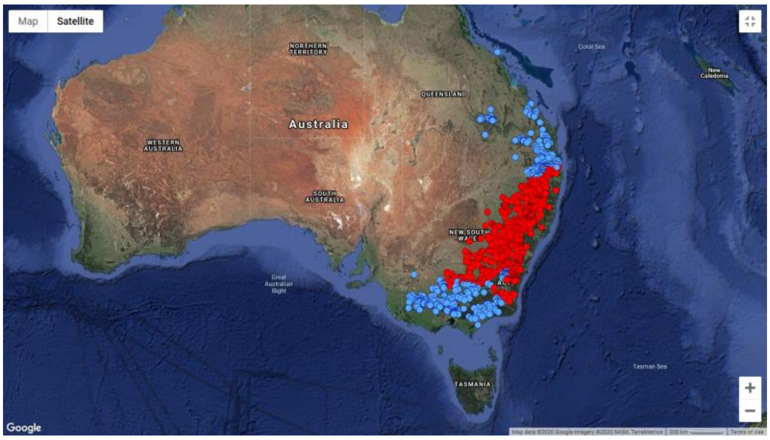


Figure 4: Example Species Occurrence Map - Eucalyptus melliodora (Yellow Box)

iii) Produce 'climate envelope graphs' for each species

'Climate envelope graphs' were produced from the current occurrence sites for each species using annual and quarterly (12 week) data on temperature and rainfall at each site, using Niche Finder. The Niche Finder database has data on multiple climate variables at current occurrence sites, mostly based on data from the period 1970 to 2013. Scatterplots were generated of two variables: temperature (X axis) and rainfall (Y axis).

Variables were selected from the Niche Finder database for three scatterplots: 1) annual average temperature and rainfall, 2) hottest quarterly (3 month) average temperature and driest quarter rainfall, and 3) coldest quarterly average temperature and wettest quarterly rainfall respectively. The variables for the hottest and driest quarters are not necessarily the same three month periods, and likewise the variables for coldest and wettest quarters are not necessarily the same three month periods.

An example of the scatterplot of current occurrences by annual average temperature and rainfall for *Eucalyptus melliodora* is shown here. See Appendix 2A for detailed instructions on how to generate all three scatterplots for each species.

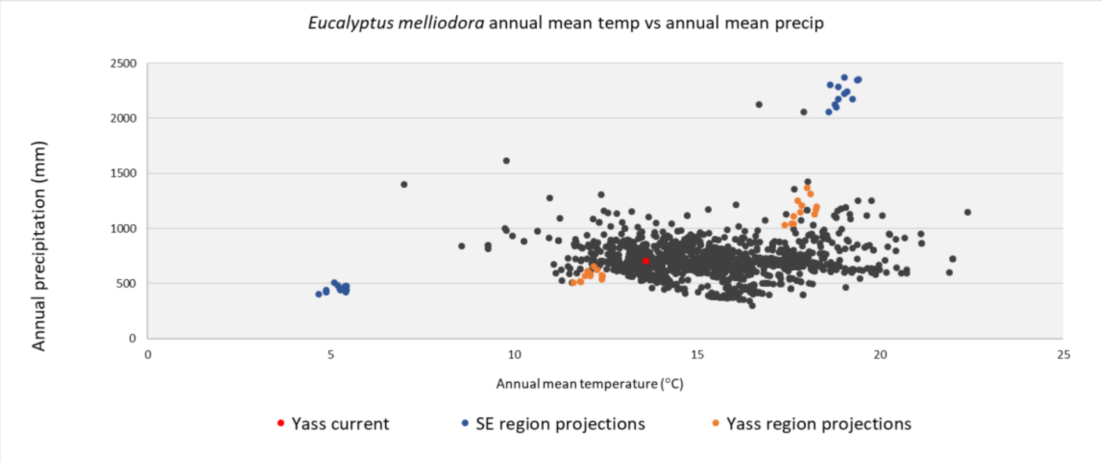


Figure 5: Example Annual Climate Envelope Graph - *Eucalyptus melliodora* (Yellow Box)

iv) Overlay the climate envelope graphs with the range of projected climate for Yass +40km

The climate envelope graphs are overlaid with the range of projected climate variables for the Yass region in 2070, to assist with identifying species most likely to tolerate climate change. The projected climate data were provided by DPIE as an Excel template. See Appendix 2C for instructions on using Niche Finder data with the Excel template to create the climate envelope graphs overlaid with the projected climate for Yass region, shown below as a brown rectangle. The graphs for each species can be requested from YAN's Climate Ready project officer by email climateready@yan.org.au.

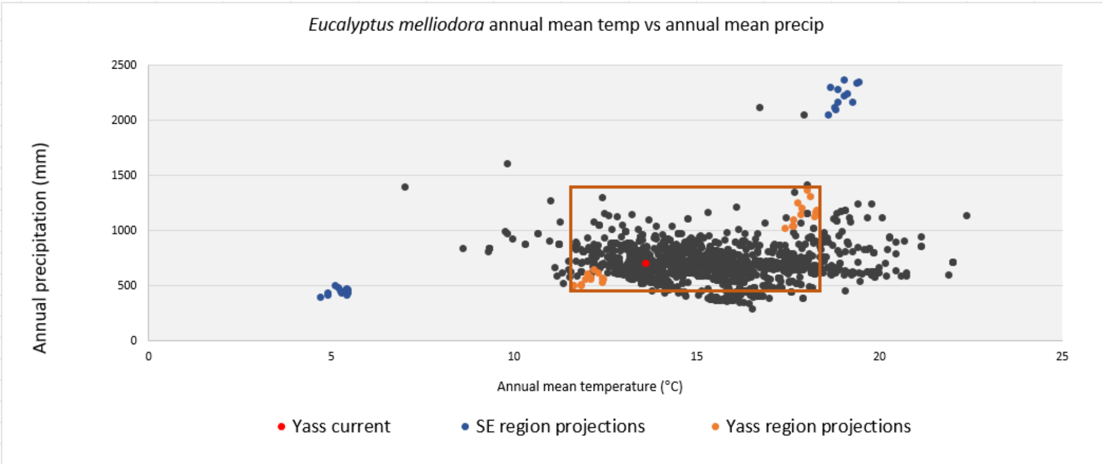


Figure 6: Example Yass Region Climate Envelope Graph - *Eucalyptus melliodora* (Yellow Box)

v) *Interpret the climate envelope graphs to assess each species as likely 'climate change tolerant' or not*

To interpret the graphs regarding likely tolerance to the projected climate, the range of temperature and rainfall that occurs in the extent of the current species distribution is assessed in relation to the projected range of those variables for the Yass region in 2070. The full range of projections for Yass in 2070 from the 12 climate models is shown in the Introduction and Appendix 2C.

During this assessment phase, more weight is placed on the hotter end of the range of temperature projections (see rationale in Part 1). We did this by making sure that species distribution reached the upper limit of the projected temperature range, being less concerned if the distribution did not reach the lower limit. The upper end of the range is about 5 degrees hotter than Yass region historically.

As projected rainfall is so uncertain, ranging from a possible 500mm to 1400mm annually, each species was assessed for separate tolerance to "hotter/drier", and "hotter/wetter" conditions.

More weight was also placed on the annual data compared to quarterly data where inconsistencies were occasionally present.

Detailed instructions on interpretation are given in Appendix 2A. This aims to maintain standardisation across species and personnel working on the graphs. There are six variables from the species climate envelope graphs to assess whether the species is 'likely to be tolerant to climate change in Yass region', and the interpretation is coded as 'Yes'/'Marginal'/'No'. An overall assessment was based on these six variables.

The six variables are shown in the table below, and the final column is an overall assessment.

Table 3: Climate Tolerance Assessment Template

Conclusion re likely tolerance to 2070 (Yass +40km) climate projections

Species name	Annual temp	Annual rain	Hottest Quarter temp	Driest Quarter rain	Coldest Quarter temp	Wettest Quarter rain	Likely Overall Tolerance

An example of a completed assessment is shown for *Eucalyptus melliodora* below.

Table 4: Example Yass Region Climate Tolerance Assessment

Species name	Annual Temp	Annual Rain	Hottest Quarter Temp	Driest Quarter Rain	Coldest Quarter Temp	Wettest Quarter Rain	Evidence for Likely Overall Tolerance
Eucalyptus melliodora	Yes+	Yes hot/dry Yes hot/wet	Yes	Yes hot/dry No hot/wet	Yes +	Yes hot/dry Yes hot/wet	**Yes+ hot/dry** **Yes hot/wet**

A concluding explanatory paragraph is also written for each species as part of the assessment.

vi) Checking the results of species assessment

We instituted a checking process for the assessment of species for two reasons. Firstly, we found it a good policy to have at least two people looking at the graphs independently as there is a degree of subjective assessment involved. Secondly, it is easy to pick up incorrect data from Niche Finder, so checking the data are correct was important. See Appendix 2D for a description of how the checking process was carried out.

Results of Species Assessment: Likely tolerance of 80 species to Climate Change in Yass region

The results of the climate tolerance assessments for the Yass area are summarised below and details for each species can be requested by emailing climateready@yan.org.au.

Species listed here were considered "likely to have a moderate to high degree of tolerance to projected climate change in the Yass region" if the last column in the concluding assessment box shown in step (v) above labelled "Evidence for Likely Overall Tolerance" did NOT include BOTH the following: 'NO hot/dry' AND 'NO hot/wet'.

This means that species in this list are assessed as likely to tolerate increased temperatures, but not necessarily both hotter/wetter conditions, AND hotter/drier conditions. While the species occur currently in areas that are hotter than Yass, they tend to be in either hotter and wetter regions, OR hotter and drier regions.

Note: these assessments have been generated from desktop analysis using the methods described above. This may change as more information and different assessment methods become available.

Local plant species likely to have a moderate to high degree of tolerance to projected climate change in the Yass region

These species currently occur in the Yass region but also in areas that experience moderate to strong similarities in highest temperature and overall rainfall to what we expect in the Yass region in future years (2070).

Eucalypts: White Box (*Eucalyptus albens*), Blakely's Red Gum (*Eucalyptus blakelyi*), Apple Box (*Eucalyptus bridgesiana*), River Red Gum (*Eucalyptus camaldulensis*), Hill Redgum (*Eucalyptus dealbata*), Red Stringybark (*Eucalyptus macrorhyncha*), Yellow Box (*Eucalyptus melliodora*), Grey Box (*Eucalyptus microcarpa*), Inland Scribbly Gum (*Eucalyptus rossii*), Mugga Ironbark (*Eucalyptus sideroxylon*)

Other trees: Black She-Oak (*Alllocasuarina littoralis*), Drooping She-Oak (*Allocasuarina verticillata*), Kurrajong (*Brachychiton populneus*), Black Cypress Pine (*Callitris endlicherii*), River She-Oak (*Casuarina cunninghamiana*)

Wattles: Box Leaf Wattle (*Acacia buxifolia*), Deane's wattle (*Acacia deanei* subsp. *paucijuga*), Western Silver Wattle (*Acacia decora*), Spearwood (*Acacia doratoxylon*), Hickory Wattle/ lightwood (*Acacia implexa*), Blackwood (*Acacia melanoxylon*), Kangaroo Thorn *(Acacia paradoxa*), Red Stem Wattle (*Acacia rubida*), Prickly Moses (*Acacia ulicifolia*), Varnish Wattle (*Acacia verniciflua*)

Other shrubs: Australian Blackthorn (*Bursaria spinosa* subsp. *lasiophylla*), Sweet Bursaria (*Bursaria spinosa* subsp. *spinosa*), Crimson Bottlebrush (*Callistemon citrinus*), Lemon Bottlebrush (*Callistemon pallidus*), River Bottlebrush (*Callistemon sieberi*), Cough Bush (*Cassinia laevis*), Shiny Cassinia (*Cassinia longifolia*), Broom Bitter Pea (*Daviesia genistifolia*), Narrow Leaf Bitter Pea (*Daviesia mimosoides*), Small Leaf Parrot Pea (*Dillwynia phylicoides*), Narrow Leaf Hop Bush (*Dodonaea viscosa* subsp. *angustissima*), Sticky Hop Bush (*Dodonaea viscosa* subsp. *cuneata*), Australian Indigo (*Indigofera australis*), Kunzea/Burgan (*Kunzea ericoides*)

Flowers: Bulbine Lily (*Bulbine bulbosa*), Billy Button (*Chrysocephalum apiculatum*), Clustered Everlasting Daises (*Chrysocephalum semipapposum*), Blue Flax Lily (*Dianella revoluta*), Purple Coral Pea (*Hardenbergia violacea*), Hoary Sunray (*Leucochrysum albicans*), Sticky Everlasting (*Xerochrysum viscosum*)

Grasses: Wallaby Grasses (*Austrodanthonia spp*) (*Rytidosperma caespitosum*), Tall Sedge (*Carex appressa*), Redanther Wallaby Grass (*Joycea pallida*) (*Rytidosperma pallidum*), Spiny Headed Mat Rush (*Lomandra longifolia*), River Tussock (*Poa labillardierei*), River Club Rush (*Schoenoplectus validus*), Kangaroo grass (*Themeda triandra*)

Local plant species not so likely to tolerate projected climate change in the Yass region

These species do NOT currently occur in areas that experience highest temperatures and overall rainfall similar to what we expect in the Yass region in future years (2070).

Eucalypts: Argyle Apple (*Eucalyptus cinerea*), Silver Gum (*Eucalyptus crenulata*), Broad Leaved Peppermint (*Eucalyptus dives*), Long Leaved Box (*Eucalyptus goniocalyx*), Brittle Gum (*Eucalyptus mannifera*), Snow Gum (*Eucalyptus pauciflora* subsp. *pauciflora*), Red Box (*Eucalyptus polyanthemos*), Candlebark (*Eucalyptus rubida* subsp. *rubida*), Ribbon Gum / Manna Gum (*Eucalyptus viminalis*)

Wattles: Gold-dust Wattle (*Acacia acinacea*), Silver Wattle (*Acacia dealbata*), Spreading Wattle (*Acacia genistifolia*), Ploughshare Wattle (*Acacia gunnii*), Woolly Wattle (*Acacia lanigera*), Black Wattle (*Acacia mearnsii*)

Other shrubs: Dolly Bush (*Cassinia aculeata*), Hop Bitter Pea/ broad leaf bitter pea (*Daviesia latifolia*), Slender Bitter Pea (*Daviesia leptophylla*), Wooly Grevillea (*Grevillea lanigera*), Small Fruited Hakea (*Hakea microcarpa*), Silky Hakea (*Hakea sericea*), Prickly Tea Tree (*Leptospermum continentale*), Woolly Tea Tree (*Leptospermum lanigerum*), Silver Teatree (*Leptospermum multicaule*), River Tea Tree (*Leptospermum obovatum*), Rough-barked Honey-myrtle (*Melaleuca parvistaminea*)

Flowers: Blue Devil (*Eryngium ovinum*)

To request detailed assessment reports on each species email climateready@yan.org.au.

PART 3: OBTAINING ADMIXTURE SEED FOR SELECTED SPECIES FROM SUITABLE PROVENANCES

The aim of the project is to grow revegetation tubestock in the YAN nurseries that is 'Climate Ready'. This involves selecting suitable admixture seed provenances to enhance genetic diversity, then obtaining seed from suppliers. As described in Part 1, the seed sourcing strategy used in this project is basically "Admixture" with a bias to "Climate-Adjusted".

Translating Provenance Strategy into Practice

Conceptually it is possible to use the climate information about a species' distribution shown in the scatterplots in the detailed results in Part 2 to identify specific sites to source seed according to particular climate characteristics. However, we found that this does not match the way that seed collectors or suppliers work and would require substantial analysis effort that would largely remain unused in practice. Consequently, we chose our approach for practical reasons, while still remaining focussed on achieving sufficient genetic diversity in the seed stock to meet the aim of the project. The criteria used to assess whether the seed is likely to have the required genetic diversity are shown in Box 2 below.

Box 2: Criteria for Assessing Admixture Seed Provenance Sites

i. There should be a minimum of six populations from at least four bioregions represented in the seed collected for each species;
ii. There should be a minimum population of 100 plants at the sites from which seeds are collected, preferably from 10+ plants;
iii. One provenance population should be 'Local' (the region in which the nursery-raised material is expected to be planted);
iv. There should be a spread of sites across the species' whole distribution and climate range, with some bias towards hottest and driest provenances;
    - There is at least one site representing HOT (the high temperatures of the upper end of the 'Hottest' quarter climate envelope); and one site representing DRY (the lower end of rainfall in the 'Driest' quarter climate envelope);
    - There is at least one site representing the projected climate range for Yass.

The first criterion ensures a spread across different environments as the 89 IBRA7 bioregions are regions based on similar ecosystems. A map outlining the current occurrence sites with bioregions can be created for each species and is shown in Appendix 3E. More information on bioregions is available here: https://www.awe.gov.au/agriculture-land/land/nrs/science/ibra#ibra (Department of Agriculture, Water and the Environment).

The second criterion ensures that the seed is from a site where the number of plants is sufficient to give good genetic diversity among seeds through cross pollination. Isolated single plants, or small stands of a species means that cross pollination cannot occur effectively, and seed is less likely to be of high genetic quality even if the plant(s) look healthy.

The third criterion ensures that the local genetics are included in the mix.

The fourth criterion ensures the seed collation has a spread across the geographic distribution and climate range of a particular species, with some bias towards hotter and drier sites. It also ensures that at least one site has a current climate analogous to the projected climate for Yass. We created a rough map of analogue regions currently experiencing climate similar to that projected for Yass region 2070 to assist in this process (shown in Figure 7).

We decided to exclude sites in SA, NT and WA as these very distant regions may be more likely to be incompatible with Yass region due to greater differences in soil and other characteristics.

We opted to work on a larger "Area" level for selecting provenance sites during the procurement stage as we found this to be more practical, and the bioregions were checked later. The five "Areas" we work with are widespread sections of NSW (Local, Coastal, Western slopes, Far West), plus south-east Queensland, and Victoria. These widespread "Areas" are not recognised formally but are a practical guide when looking for suitable seed suppliers.

The practical steps to find admixture seed are basically (a) to find suitable provenance Areas, (b) procure seed from suppliers in these Areas, and then (c) check the adequacy of the overall admixture sites using the criteria shown in Box 2 above. The steps are outlined below, and more details are shown in a worked example in Appendix 3E.

Analogue regions for seed procurement

The geographic areas of eastern Australia that have recently had climate conditions similar to the projected range of temperatures and rainfall for Yass +40km, can be called the Yass projected climate 'Analogue Areas'. The approximate analogue areas are shown in white and green in Figure 7 and 8 below. These analogue areas are broad, reflecting the wide range of projected climate variables.[3]

[3] The map in Figure 7 is based on the Yass +40km projected climate range, with approximate average annual temperature range of 12-18°C, and rainfall of approx 500-1400mm. The map in Figure 8 shows the outcome from a warmer outlook, with annual temperature range of 14-18°C, and rainfall of approx 500-1400mm. The maps have been generated through spatial searches on the Atlas of Living Australia website. See the introduction for more details about projected climate *ranges*, which includes colder temperatures.

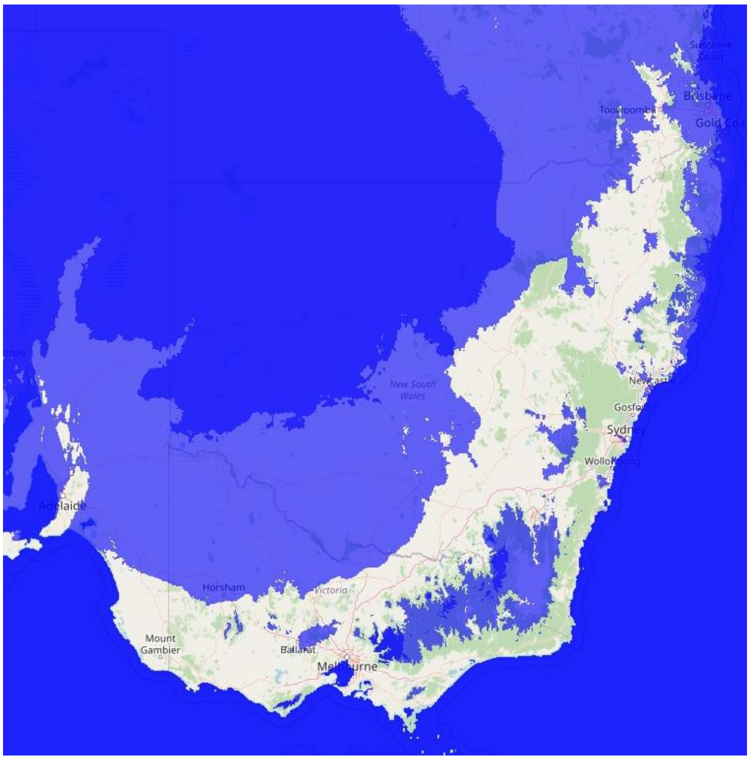


Figure 7: Climate analogue (white and green area) for the projected future climate of Yass based on 500-1400mm annual precipitation and 12-18°C annual mean temperature

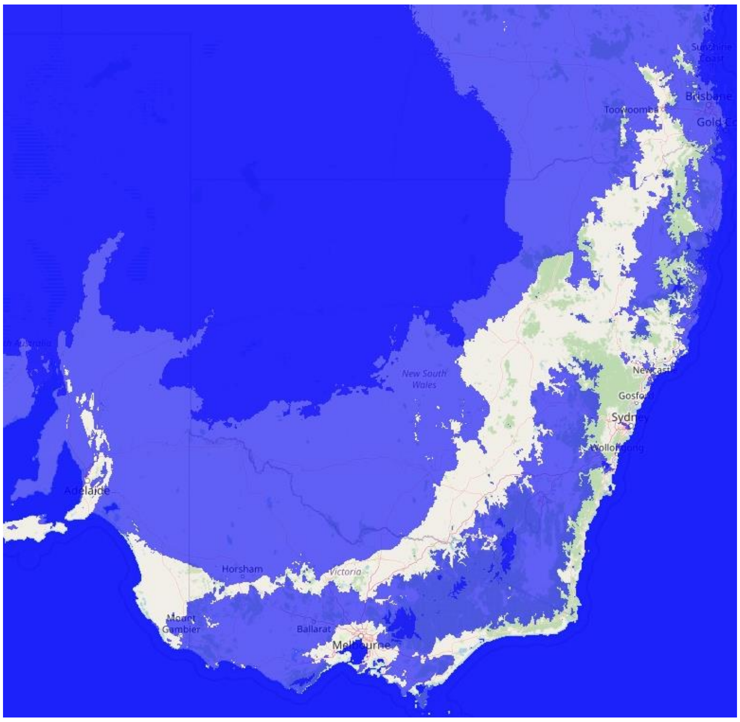


Figure 8: Climate analogue (white and green area) for the projected future climate of Yass based on 500-1400mm annual precipitation and 14-18°C annual mean temperature

Methods

First create a new seed provenancing record for each species (using Appendix 3E as a basis) and continue to add the results of each step to the record.

(a) Find Suitable Provenance Areas

- Examine the distribution map of the species (using the Atlas of Living Australia);
- From the distribution map, and the map of areas with current climate similar to the projected climate for the Yass region, select potential seed provenance Areas. That is, from NSW (Local, Coastal, Western slopes, Far West), Queensland and Victoria as appropriate. Provenance sites should always include:
  - a site that is 'Local'
  - a site with current climate similar to the projected climate for the Yass region;
  - major areas in the distribution
  - areas that comprise the outer bounds of the distribution (especially hottest and driest, but ignoring outliers).

(b) Find Seed Suppliers and Procure Seed

- Find seed suppliers in the selected Areas, starting with Greening Australia in the ACT which sources from a range of suppliers. Seed suppliers can be found via the internet and other resources;
- Check the seed provenance sites and details of seed collection with the seed supplier regarding location, plant population size and type (remnant or not), and number of plants that seed was taken from;
- If provenance seems suitable, obtain seed.

c) Assess the Adequacy of the Admixture Seed

- After seed has been acquired from multiple sites/suppliers, assess whether the spread of the admixture provenance sites is adequate for each species;
- Show the seed source/provenance sites on a map - use Google maps. See Appendix 3A for details on how to do this;
- Find information on the climate of each provenance site, using Atlas of Living Australia (ALA), and put the information into a table. See Appendix 3B;
- Show the provenance sites on the species' climate envelope graphs that were created in Part 2 of this report. This requires information about the climate of the provenance sites from ALA, then adding the sites to the Climate Envelope Excel Spreadsheet. See Appendix 3C for details about how to do this;
- Check that the criteria for adequate admixture (see Box 2) have been met to the largest extent possible. Write a summary paragraph about the adequacy of the admixture seed.

A fully worked example of obtaining admixture seed and then assessing its adequacy is shown in Appendix 3E.

PART 4: INCORPORATION OF CLIMATE READY STRATEGIES INTO YAN LANDCARE NURSERIES AND REVEGETATION ACTIVITIES

This section describes how practices in the YAN nurseries have developed in conjunction with this project and how Climate Ready strategies are being incorporated into the everyday practices in the YAN nurseries for revegetation activities.

Attempts are being made to obtain Admixture seed with a Climate-Adjusted bias for 37 species. These were selected from the 60 species that were assessed as likely to be climate change tolerant in the Yass region (out of a total of 80 species assessed). The rationale for using an admixture seed provenance strategy was explained in Part 1.

Background

There are four nurseries in the Yass Area Network of Landcare Groups belonging to three different Landcare groups (Bowning-Bookham, Murrumbateman and Yass). These had started at different times between 2005 and 2018 and are located over an area of about 50km. Two nurseries are on public land and are within a fenced perimeter, and two nurseries are on private land and are run principally by the landowner with volunteer assistance. The nurseries on public land also have a manager or small management team and engage additional assistance from Landcare members in the local group as needed. All nurseries are run and supported by volunteers (that is, there are not any paid staff) and aim to provide plants for their local community, although the objectives of the nurseries differ to some extent. Each nursery grows around 4,000 to 8,000 tubestock per year to support the projects and members of the various Landcare groups.

When the Climate Ready Revegetation project began, a YAN Nursery Managers Group was formed that met approximately every 3-4 months, either at the Yass nursery (the most central location) or online using Zoom. All four nurseries were regularly represented and discussion centred on exchange of ideas, information and practices, and discussion of the new project. The YAN chairperson ran the meetings with an agenda formed by all the participants who have got to know each other. Topics included:

- Labelling of plants
- Range of species grown
- Species background information
- Germinating difficult species
- Distribution of plants, including sales by some groups
- Potting mix used
- Fertiliser use
- Watering systems
- Organising volunteers
- Sowing practices
- Record keeping
- Monitoring after planting into revegetation

- Adoption of a common set of climate-ready species grown, known as the 'Climate Ready Nursery List'.

While initially these meetings were focussed on developing nursery practices to support implementation of the trial outlined in Part 5, other outcomes from these meetings included bulk buying of potting mix and labels for plants that was shared across the nurseries, and development of a shared online area with information. Ultimately, one of the nursery managers has become the seed stock manager and is responsible for sourcing and purchasing admixture seed for all four nurseries, and for care of the seed stock.

Providing plants for the project trial

The nurseries provided the plants for the project trial. Details about the local and admixture seed, and the plants produced, are given in the following section on the trial. Prior to growing plants for the trial, substantial work was undertaken by the Nursery Managers to standardise the growing practices and consumables used in the nurseries to ensure consistency of methods and resulting tubestock for the trial. A manual was produced for this purpose.

In growing plants for the trial, each nursery was responsible for one species that had to be grown in a consistent manner. This activity led to discussion, standardisation and general improvements in nursery practices including standardised documentation of progress of germination and health of the plants. A germination test was done to ensure that all provenances used in the trial (three species with over 20 provenances in total) provided viable seed. Subsequently, details of germination and plant growth in the nurseries are being maintained for all species.

The level of detail recorded was a new activity for most nursery managers and has led to further discussion about how to maintain records as a useful source of information and as an ongoing activity.

Ongoing provision of climate ready plants through the YAN nurseries

The Nurseries agreed to work together to provide a core set of climate ready species for the YAN area. Subsequently, 37 species have been selected from the list of plants that were assessed as likely to be climate change tolerant (see Part 2 for details). Two ecologists selected this starting set that forms the Core Climate Ready Species for the YAN nurseries, as shown in Table 5. Efforts are being made to obtain admixture seed for these species (as described in previous section). The list will be open to change over time in response to feedback from nurseries and revegetation activities.

Table 5: Core list of climate ready plants for YAN nurseries

Habitat 1: Grassy Woodland lower slopes	
White Box	*Eucalyptus albens*
Blakely's Red Gum	*Eucalyptus blakelyi*
Apple Box	*Eucalyptus bridgesiana*
Yellow Box	*Eucalyptus melliodora*
Mugga Ironbark	*Eucalyptus sideroxylon*
Kurrajong	*Brachychiton populneus*
Hickory Wattle/ lightwood	*Acacia implexa*
Blackwood	*Acacia melanoxylon*
Red Stem Wattle	*Acacia rubida*
Deane's wattle	*Acacia deanei* subsp. *paucijuga*
Western silver wattle	*Acacia decora*
	Acacia ulicifolia var brownii
Varnish wattle	*Acacia verniciflua*
Sweet Bursaria	*Bursaria spinosa* subsp. *spinosa*
Small Leaf Parrot Pea	*Dillwynia phylicoides*
Narrow Leaf Hop Bush	*Dodonaea viscosa* subsp. *angustissima*
Australian Indigo	*Indigofera australis*
Bulbine Lily	*Bulbine bulbosa*
Billy Button	*Chrysocephalum apiculatum*
Purple Coral Pea	*Hardenbergia violacea*
Sticky Everlasting	*Xerochrysum viscosum*
Habitat 2: Dry Sclerophyll poor soils, upper slopes and ridges	
Red Stringybark	*Eucalyptus macrorhyncha*
Inland Scribbly Gum	*Eucalyptus rossii*
Drooping She-Oak	*Allocasuarina verticillata*
Black Cypress Pine	*Callitris endlicherii*
Narrow Leaf Bitter Pea	*Daviesia mimosoides*
Box Leaf Wattle	*Acacia buxifolia*
Spearwood	*Acacia doratoxylon*
Kangaroo Thorn	*Acacia paradoxa*
Shiny Cassinia	*Cassinia longifolia*
Clustered Everlasting Daises	*Chrysocephalum semipapposum*
Habitat 3: Damp and/or poorly drained sites including streambanks, dams and depressions	
River bottlebrush	*Callistemon sieberi*
Broom Bitter Pea	*Daviesia genistifolia*
Kunzea	*Kunzea ericoides*
Tall Sedge	*Carex appressa*
River Tussock	*Poa labillardierei*
River Club Rush	*Schoenoplectus validus*

Ongoing Nursery Managers Collaboration

In addition to growing at least the core species listed in Table 5, the YAN Nursery Managers have agreed to continue to work together, including sharing resources across the nurseries. The Seed Stock Manager sources and supplies all four nurseries with appropriate admixture seed. This sourcing work began in April 2021 and each Landcare Group with a nursery in YAN contributes to the purchase of the common seed collection.

PART 5: TRIAL TO ASSESS SURVIVAL OF PLANTS GROWN FROM LOCAL AND NON-LOCAL SEED PROVENANCES

Background

As outlined in the introduction, the aim of the overall project is to assist the long-term survival of native plantings under climate change in the YAN Landcare region through judicious selection of seed provenance to enhance genetic diversity.

The overall project is based on some underlying premises summarised in the following points:

- Some local plant species may tolerate climate change more than others. Those with a wide distribution, particularly extending into hotter areas, are more likely to tolerate climate change – providing the appropriate genotypes can disperse into cooler regions through natural or assisted dispersal.
- Genetic diversity is likely to improve adaptive responses to climate change, although the specifics of which gene combinations will contribute to survival is unknown. To maximise adaptative potential, we adopted an ***admixture provenance*** strategy to source seed for revegetation in our region (as described in Part 1). The objective of admixture provenancing is to establish a range of genotypes from widely distributed populations at planting sites. This provides the opportunity for genetic recombination and adaptation in future plant generations.
- We consider the admixture strategy the best option at this time of great uncertainty regarding both environmental conditions and the emissions-reduction pathway. In particular, rainfall projections in our Yass Valley region are uncertain. Our approach will be modified in response to future results and scientific findings as required.

Until climate change concerns emerged in recent years, it was generally considered best practice in Australia to use local seed in revegetation activities. This was based on the notion that plants would be best adapted to local conditions if they were grown from locally sourced seed. As a result, the historical preference for plants grown from local seed has led to a lack of knowledge about the survival of plants grown from *non-local* seed.

Undertaking revegetation is resource intensive work and local Landcare groups are keen to ensure that the vegetation planted now is likely to survive and endure in the landscape. While only decades will show the long-term results of revegetation work undertaken now, an essential first step is to understand whether plants grown using the admixture seed sourcing strategy will survive in the short-term.

Therefore, we decided to conduct a simple planting trial to assess if the survival of plants from combined non-local (admixture) provenances is comparable to the survival of plants of local provenance. The trial is planned to last 3-5 years. Note that in this trial, the term 'non-local (admixture)' refers to plants grown from a mixture of seed from various provenances, but does not include local seed.

The rationale for using two treatments (local versus blended non-local provenances) rather than conducting a trial comparing individual provenances is as follows:

- It is testing the real-life situation that YAN nurseries will be using (i.e. blended admixture seed). It is not practical to grow individual provenances of multiple species in the nurseries on an ongoing basis due to space limitations and the difficulty of managing and maintaining separate sections for so many different treatments.
- The core question is whether the admixture plantings would provide a seedling establishment rate that was comparable with the local plantings, and was thus able to launch a wider array of genotypes (but not necessarily a greater number of plants) into the landscape than that provided by the local plantings;
- The trial is not trying to assess the success of specific provenances, as we are not trying to test whether to source future seed from specified sites but rather the survival of plants from local and non-local provenances.
- Keeping the trial manageable for practical purposes was considered vitally important, taking into account the volunteer basis, limited nursery resources, limited resources to establish the trial, and the demands of monitoring a large trial, making it vulnerable to becoming neglected over the years. A much larger and more complex trial would be needed to test the survival of plants from individual provenances (the number and size of sites would be prohibitive, as well as the additional workload on the nursery volunteers).

Hence the choice to have only two treatments, local *versus* a non-local provenance mix. This reflects relevance to ongoing nursery procedures, an achievable design and confidence in results.

In addition, it is important to note that the current trial is not a test of the success of the admixture strategy in the longer term, rather a test of the first stage. The overall success of local and non-local plantings can only be assessed from the persistence of the species at a site after many generations and future climate change, something that will exceed our lifetimes. This requires plants to be established in a protected, functional landscape, where continuing regeneration is likely to occur.

Aim of the trial

The aim of the trial is to answer the following research question:

> *Is there a difference in short-term survival of plants from local seed provenance, compared with plants from a non-local (admixture) seed provenance?*

In this trial 'local' was defined as the YAN region, including Bookham, Yass, Murrumbateman, Sutton, Captains Flat and Canberra. 'Non-local' was defined as comprising all other regions.

Methods

The trial was designed to test the research question over a number of sites that were spread over approximately 50km radius in the Yass Valley region. We decided to monitor the survival of plants for three to five years.

Outcome measure

Survival data is collected in Spring each year. The first was 6 months after planting (Spring 2021). Any sign of life is counted as 'alive' and the finding 'not alive' is only recorded if the plant does not have any sign of possible recovery, such as being completely dry and brittle, or missing. The assessment of 'uncertain' is allowed if unsure.

Survival was selected as the only outcome measure for the following reasons: it is vitally important to indicate whether plants grown from seed sourced from non-local areas are able to begin to persist; the outcome of survival is simple to record, does not require expert knowledge, and relates directly to the aim of the trial. A time frame longer than five years was considered to be unrealistic in a community-run trial, as was the collection of more complex data.

Implementation

The implementation of the trial involved several stages – species selection and seed sourcing, growing tubestock, recruiting landholders and selecting sites, design of plantings, planting tubestock, and monitoring survival. Each of these stages is described below.

Species selection and seed sourcing for the trial

We undertook initial desktop climate tolerance assessments in 2018 and 2019 to select species for the trial that were considered likely to be climate change tolerant. We aimed to include a large tree, a small tree, a shrub and a ground cover to approximate the layers in local ecosystems. Initially about 20 potential species were considered, then after development and refinement of the desktop climate tolerance assessment method (as described in Part 2 and Appendices 2A-D), we applied these methods to assess likely climate tolerance of these potential species for the trial. We also asked Greening Australia to provide advice on these species regarding whether we could expect to obtain sufficient local and non-local seed. In light of the assessment and advice, we selected four species to include in the trial: *Eucalyptus melliodora* (large tree), *Acacia deanei* sbsp. *paucijuga* (small tree), *Dodonaea viscosa* subsp. *angustissima* (shrub), *Chrysocephalum semipapposum* (forb/herb).

During 2020, we attempted to obtain up to 10 seed provenances for each of the four species, following the methods and criteria outlined in Part 3. For *Chrysocephalum semipapposum* we were only able to acquire local seed, so this species was dropped from the trial, leaving three species remaining. In addition, we were not able to source 10 provenances for each species. In the end, the team decided that there needed to be a minimum of three provenances for the non-local seed, and at least one provenance for the local seed (as detailed in Part 3). The number of provenance locations varied by species and a summary of provenances used in the trial is shown in Table 6: Summary of Seed Provenance for the Trial Full details related to seed collection factors (population size, number of donor plants, germination testing etc) are shown in Appendix 5A.

Table 6: Summary of Seed Provenance for the Trial

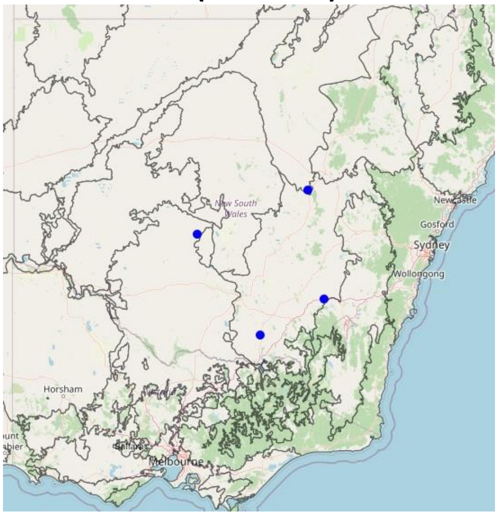
Species	No. local provenance sites	No. Non-local provenance sites
Eucalyptus melliodora	3	6 across 5 bioregions
Acacia deanei subsp. *paucijuga*	1	3 across 3 bioregions
Dodonea viscosa subsp. *angustissima*	3	5 across 3 bioregions

Geographic maps of provenance locations and the corresponding climate envelope graphs (for annual mean temp and precipitation) are shown below in Figure 9 Figure 10. These show a reasonably wide distribution of sites both geographically and across the species' climate range (see Parts 2 and 3 for more information on the climate envelope graphs).

In the climate envelope graphs (Figure 10), place names in yellow are local provenances, and those in green are non-local.

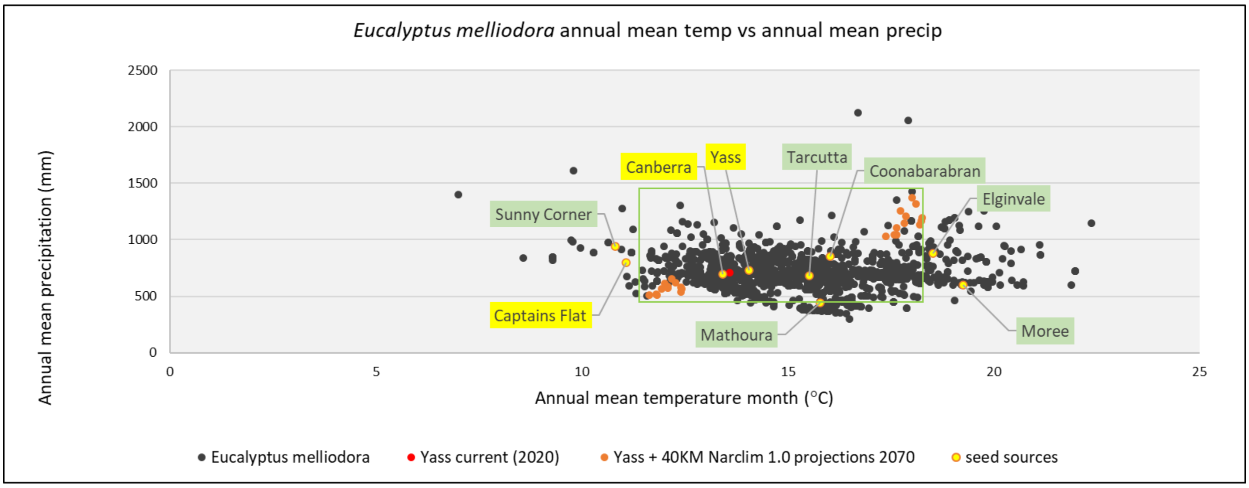
Eucalyptus melliodora** (red dots))

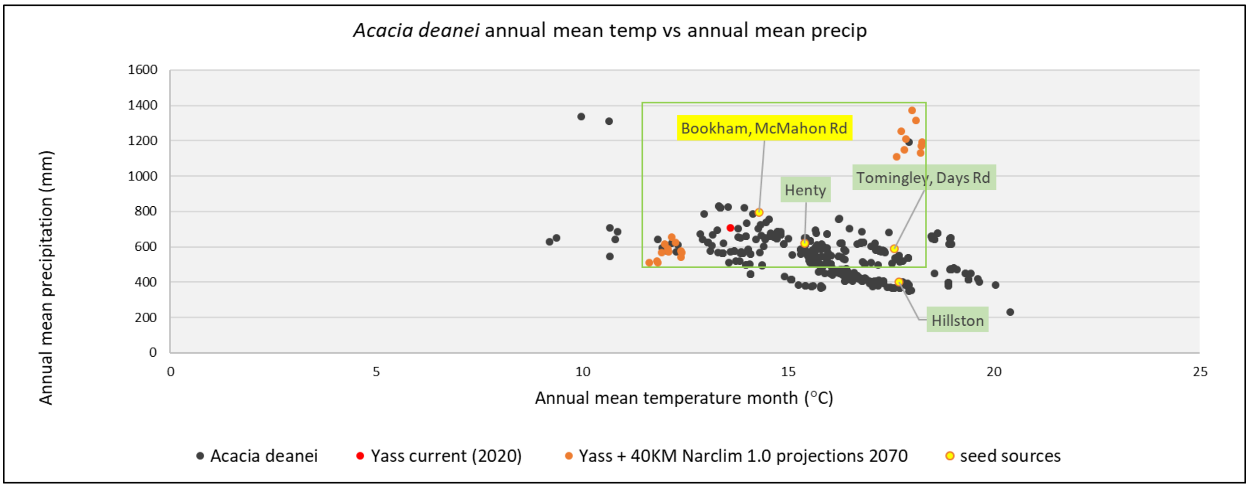
Acacia deanei **(blue dots)**



Dodonaea viscosa **(purple dots)**

Figure 9: Maps of seed provenance sites by bioregion (IBRA7)





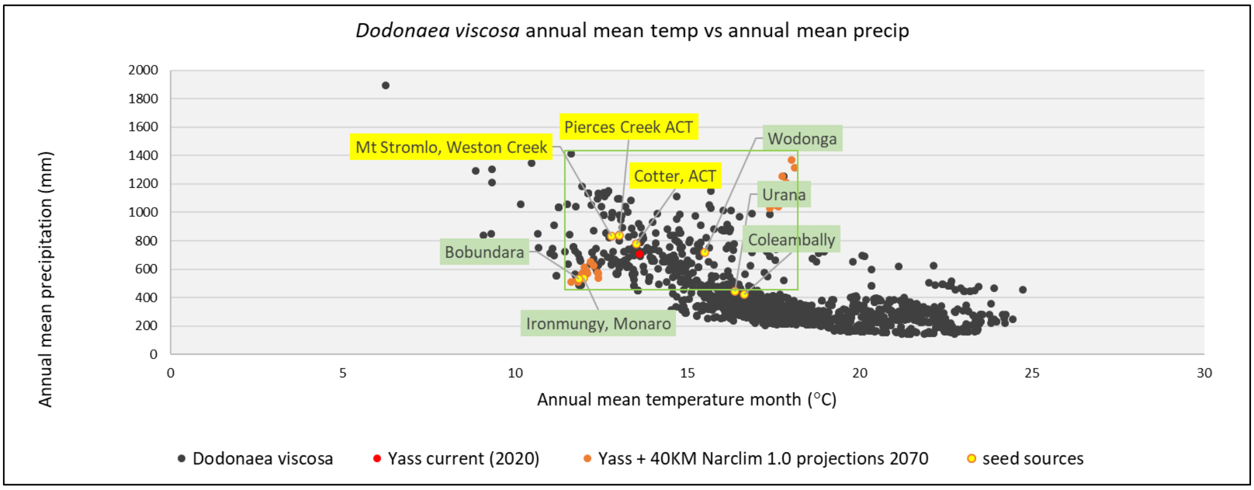


Figure 10: Climate envelope graphs showing seed provenance sites for the three trial species (annual mean temp and precipitation) yellow=local; green= non-local

Growing Tubestock for the Trial

Three of the four Landcare nurseries grew the tubestock (Yass, Bowning and Bango). One species was grown at each nursery to ensure each species had consistent growing conditions. Details about growing the tubestock were discussed with each nursery beforehand and written instructions are shown in Appendix 5F.

Before sowing in the nurseries in spring 2020, a germination test was done to check that seed from all provenances were viable (results are shown in the provenance table at Appendix 5A). Provenances were sown separately in the nurseries and germination from each individual provenance was noted in the nursery, and oversowing was undertaken if needed. Overall, germination and plant production was satisfactory from all provenances with the exception of one *Eucalyptus melliodora* provenance site (Elginvale, which produced less seedlings and contributed only half the number of plants to the non-local admixture compared to all other *Eucalyptus melliodora* admixture provenances).

Due to uncertainty regarding survival through the early growing stages, extra plants were grown over and above the number considered necessary to answer the research question (see Appendix 5C on the statistical calculation of required number). One thousand tubes were therefore sown with local seed of each species, and 1000 tubes were sown with the non-local seed for each species. This resulted in around 5000 tubestock available to include in the trial, which was more than required. Tubestock were ready for planting by mid-March 2021. A list of the number of tubestock successfully grown for each species is detailed below:

Table 7: Summary of Tubestock Grown for the Trial

Species	Number of Local Tubes Sown	Number of Local Tubestock Successfully Grown in nursery	Number of Non-local (Admix) Tubes Sown	Number of Non-local (Admix) Tubestock Successfully Grown In nursery
Eucalyptus melliodora	1020	897 (88%)	1020	862 (85%)
Acacia deanei subsp. *paucijuga*	1000	435 (44%)	1200	656 (55%)
Dodonea viscosa subsp. *angustissima*	1000	1000 (100%)	1000	1000 (100%)

The provenances for each species were grown separately in the nurseries. When selecting the required number of plants for the two treatment groups for the trial, an equal proportion of plants were taken from each provenance within each treatment group, selecting across the whole bank of plants to ensure there was no bias in selection. This was to ensure that there was not a systematic bias to selecting plants from a particular part of the nursery that could conceivably affect growth and resilience of the plants (for example, from the outside edge of the facility or some other space).

The required number of plants were then allocated to each trial site for planting, with two to six extras in each treatment group in case of mishap.

Recruiting Landholders and Selecting Sites

Landholders were recruited to host sites for the trial through a process of self-nomination after promotion of the trial at Landcare meetings, follow-up emails and articles in the YAN Landcare newsletter. An example of an advertisement and the information provided to landholders is included at Appendix 5B. This resulted in 12 landholders submitting an expression of interest that described characteristics of the site proposed for inclusion in the trial.

After the characteristics of the sites available were reviewed by an ecologist, it was decided to have two Main Sites (see following section) selected on the basis that these were large enough areas for implementation of the proposed multiple blocks and plot planting design. These would supply results with the statistical power required to answer the research question (see Appendix 5C for the statistical calculations of the required number). Additional smaller Supporting Sites (see following section) would be planted with a less rigorous design that could be more easily implemented by extra landholders wishing to take part in the trial, using the remaining plants available.

In the end, eight properties are hosting trials – two 'Main Sites' and six 'Supporting Sites', which are explained further below.

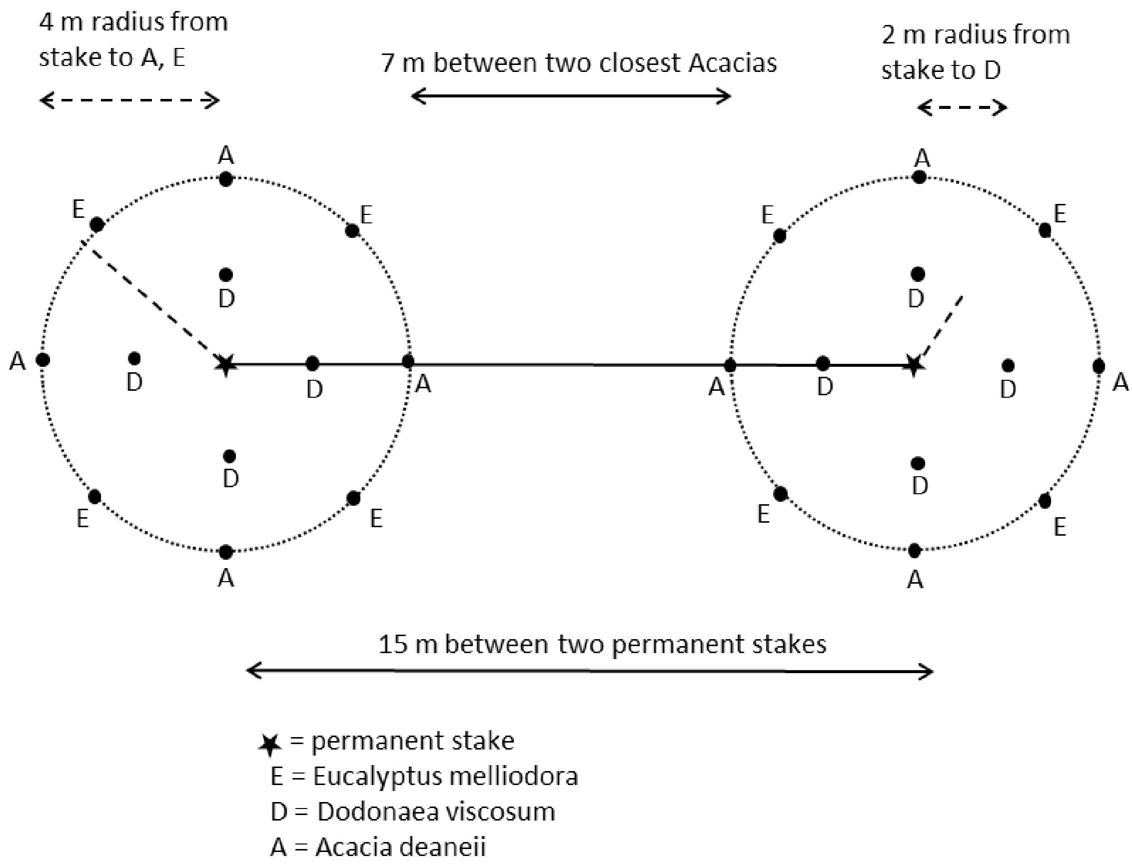
A further four landholders received a small number of plants grown from non-local seed and have been requested to update us with how well the plants survive

Design of Planting Sites

Main Sites

Each of the two main sites is approximately one hectare in total area. The design for the two Main Sites comprises a minimum of 20 blocks. Each block is made up of two plots. Within a block, the two plots are side by side and in as similar terrain as possible (i.e., paired) – one plot is planted with the three species of local provenance seedlings, the other plot planted with the three species of non-local (admixture) provenance seedlings. There are four plants of each species in each plot. This layout is shown in Figure 11 below.

Some weeks prior to planting, a team visited each of the two main sites to layout permanent stakes and markers with the design. Each block was laid out by measuring distances using a long tape measure. A few obstacles were avoided such as older trees or rocks, so that the two plots could be adjacent in similar terrain.



This Figure shows the layout of one block made up of two plots (one for each treatment). There are 4 plants of each species per plot. Each plot contains all non-local plants, or all local plants. The location of these two types of treatment plots were randomised in each block.

Figure 11: Main Sites Layout

There are four local individual plants, and four non-local (admixture) plants of each species in more than 20 blocks in each of the two main sites. (approx. 80+ local plants and 80+ non-local plants of each species at each main site). This number was calculated to be sufficient to detect a statistically significant difference between a survival rate of 50% and of 70% (or between 50% and 30%) between the two treatment groups (Local vs Non-Local mixes), at a p-value of 0.05. Details regarding statistical power are shown in Appendix 5C.

The two main sites are on land of two Landcare members about 50km apart. The detailed plans of the actual layouts on each of these properties are shown in Appendix 5D. The site locations have also been recorded on a diagram superimposed on a terrain map from Google Earth, and kept by the project team.

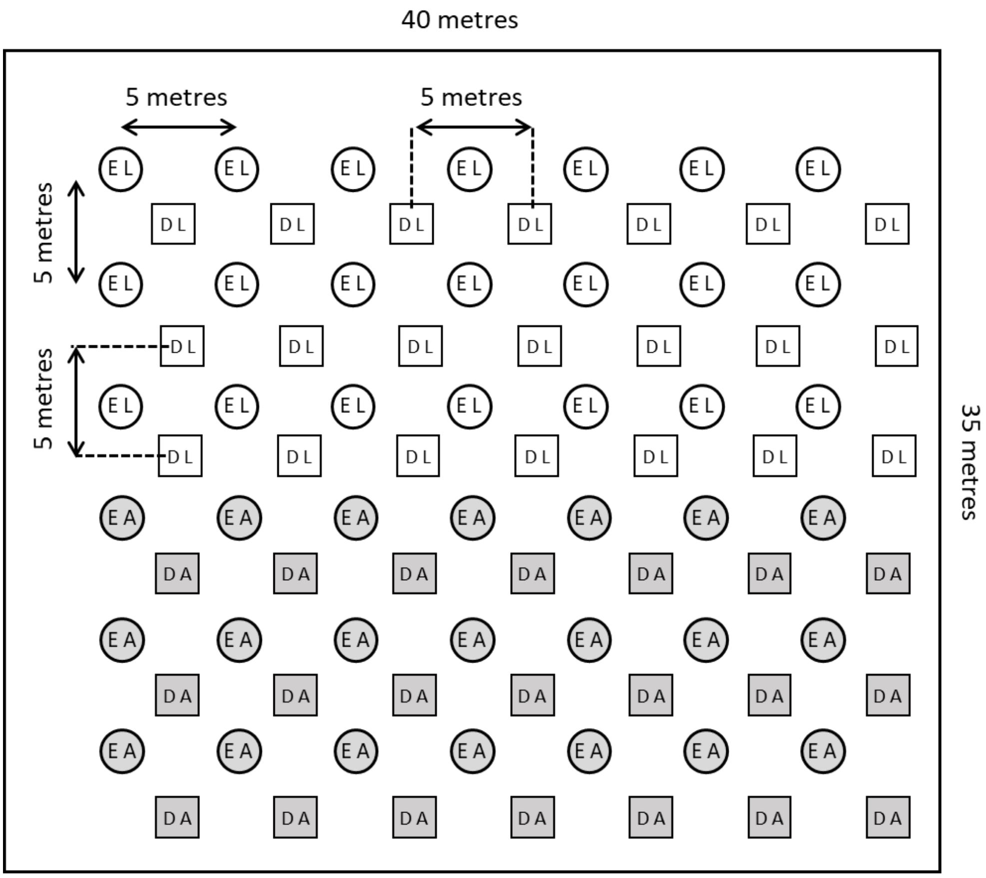
Supporting Sites

Six landholders are hosting a Supporting Site. A simpler design used for this category involved 21 plants of each of the three species for each of the two treatment groups (local and non-local). This totalled 126 plants per supporting site when three species were used. Some supporting sites were smaller in area, and after allocating plants to the two main sites, there were not enough of one species (*Acacia deanei* subsp. *paucijuga*) for all the supporting sites to have three species. Consequently, three supporting sites planted out three species (with a total of 126 plants per site), and three planted out two species only (with a total of 84 plants per site).

The layout design for the supporting sites was to have one block with two plots side by side; one plot for local plants, and the other for non-local (admixture) plants. There could be either three species or two species, as shown in Figure 12 and Figure 13 below.

Another variation of the way the plots could be laid out on Supporting Sites was to have the two plots end to end (see Figure 13). The plots were aligned to cover terrain in a way that was as similar as possible to reduce variation between the plots.

The site locations have also been recorded on a diagram superimposed on a terrain map from Google Earth.

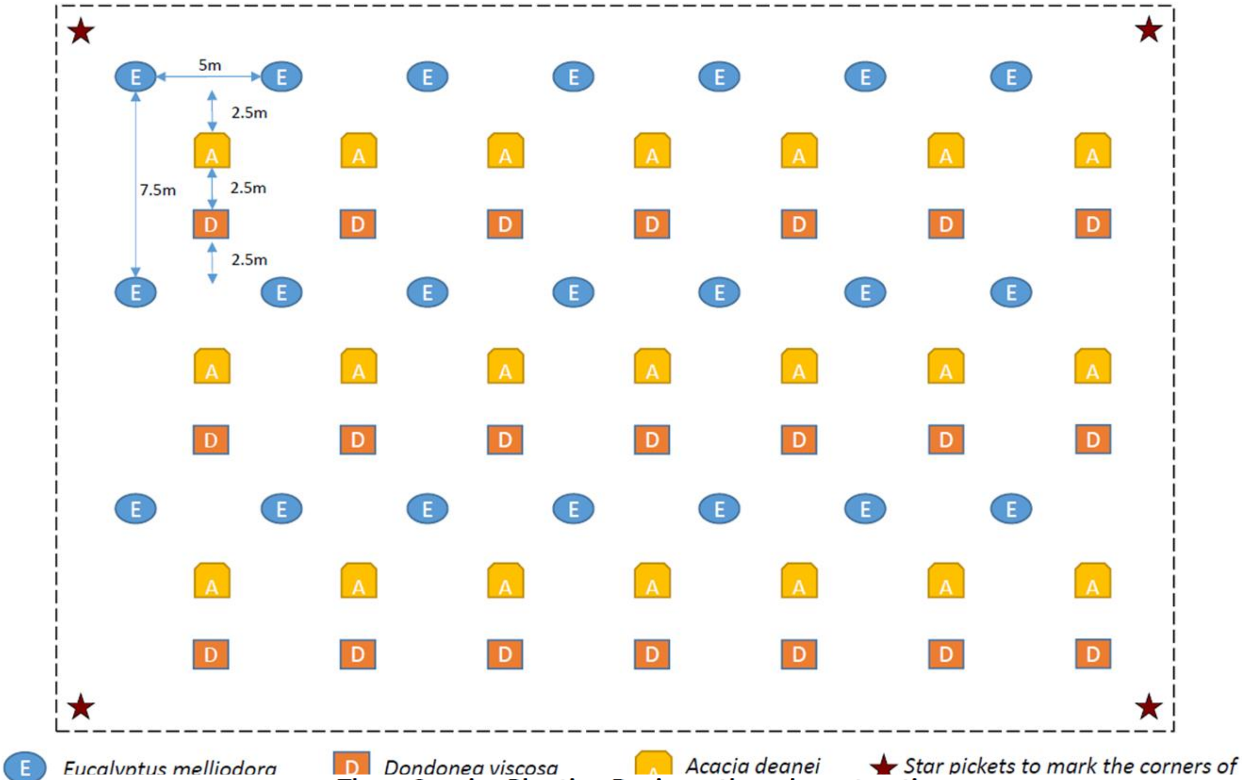


Sample design. Eucalypts (E) are arranged in a grid, 5 metres apart. *Dodonaea* shrubs (D) have the same spacing, and are interspersed between the eucalypts. Here the minimum spacing and numbers of plants are shown. Wider spacing, more plants and different plot shapes may be optional. Shaded shapes indicate admixture plants (A) open shape indicate local plants (L).

Figure 12: Sample design of Supporting Trial Site with two species

Three Species Planting Design (approx. 25 x 35m)

This is the basic layout of one planting section – please see over page for the layout options of your two sections



Three Species Planting Design – three layout options

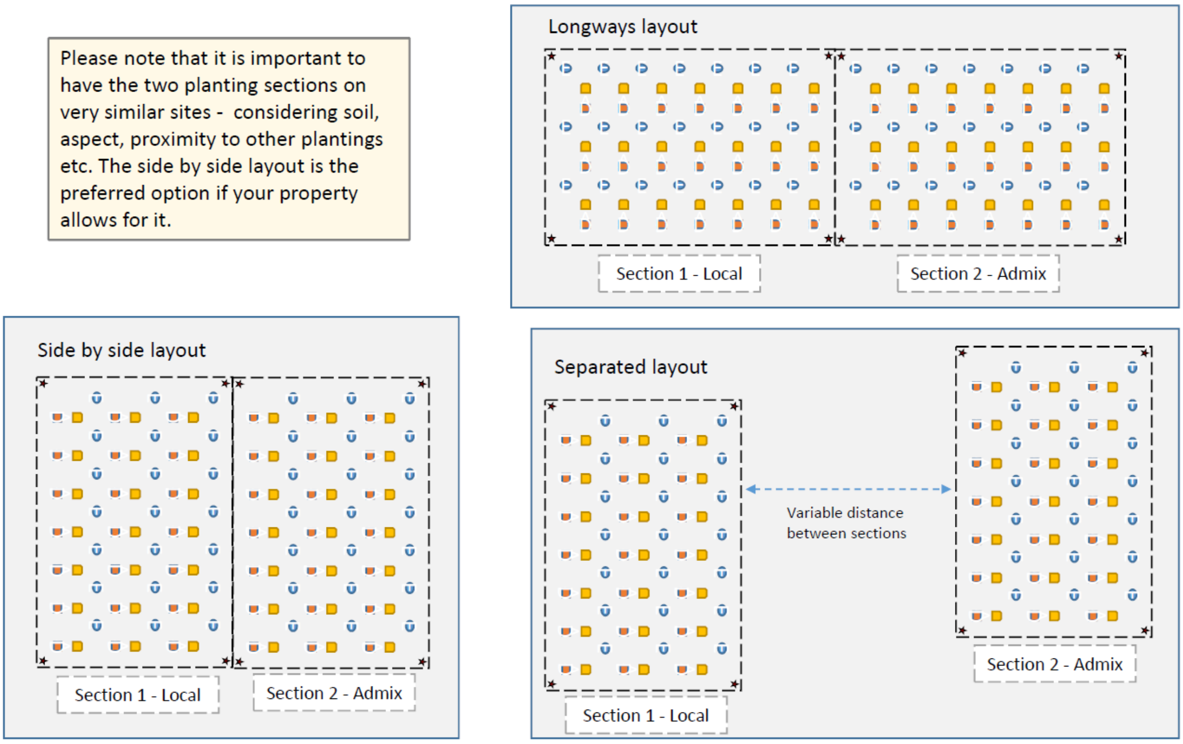


Figure 13: Sample design and layout of Supporting Trial Site with three species

Planting tubestock

Most of the participating landholders organised the planting of their own sites. Plants were provided to each site from the YAN Landcare Nurseries. Plants within the two treatment groups (local and non-local) had been randomly allocated across the whole batch so that plants from the same provenance would not be planted in the same area of the site, but were spread across its entirety.

Some planting was undertaken by the landholders alone, and others had additional support from groups of experienced volunteers. To reduce variability that could affect plant survival consistent planting techniques were applied within each site. An example of the care taken to achieve consistency at one of the main sites is given in Appendix 5G. As a minimum each plant was planted, covered with a tree guard and watered, with the blocks marked so that the local and non-local plants could be identified at a later date, and the location of species and treatments was checked at the time and corrected where necessary to match the design. There was some variation in the types of tree guards that were used across the sites, but there was consistent treatment between local and non-local within each site.

All plants were distributed and planted at both the main and supporting sites between March and early June 2021. The number of each species planted at each site are shown below.

Table 8: Number of plants and planting dates in Climate Ready Trial

Sites	Number of plants							Date of planting
		Local			Admix			
	TOTAL	E. mell	A. dean	D. visc	E. mell	A. dean	D. visc	
Main Site 1	**528**	88	88	88	88	88	88	Various days in March 2021
Main Site 2	**552**	92	92	92	92	92	92	Planted 11/4/21
Supporting Site 1	**126**	21	21	21	21	21	21	Planted approx 1/6/21
Supporting Site 2	**84**	21	21	0	21	21	0	Planted 1/4/21
Supporting Site 3	**126**	21	21	21	21	21	21	Planted 30/3/21 - 3/4/21
Supporting Site 4	**84**	21	0	21	21	0	21	Planted 30/05/2021
Supporting Site 5	**126**	21	21	21	21	21	21	Planted 6/5/21
Supporting Site 6	**84**	0	21	21	0	21	21	Planted approx 24/4/21
	1710	**285**	**285**	**285**	**285**	**285**	**285**	

Monitoring

The trial hosts of the two main sites and six supporting sites were given instructions and data sheets (in both PDF and Excel formats, see Appendices list below) and are monitoring the survival of each seedling in the trial each spring. The first data collection was after six months (October 2021), then will occur at 12 monthly intervals. There will be email reminders sent before the annual monitoring period.

The annual monitoring consists of:

1) photographs across each planting site to visually record the progress of the plants
2) data sheets that record the number of plants by species in each of 20+ plots at the main sites, and in the single plots at the supporting sites, that are alive, dead, or uncertain.

All photographs and data sheets are sent to the YAN coordinator or relevant project officer for analysis and safe keeping.

There are slight variations in the instructions for the main and supporting sites, reflecting their different layouts. The following appendices contain all the relevant monitoring information:

- Appendix 5H Email request to hosts about monitoring
- Appendix 5I Monitoring instructions for main sites
- Appendix 5J Monitoring instructions for supporting sites
- Appendix 5K Sample data sheet

Results

Current status

As mentioned above, the trial hosts monitored the survival of their plantings at the end of the 2021 when the tube stock had been in the ground for approximately 6 months. The plantings were monitored again at the end of 2022, when the plantings were around 18 months old.

When monitoring, the trial hosts are asked to determine whether each individual plant is 'alive', 'dead', or 'uncertain'. For simplicity in presenting the results, the plants that are 'alive' and 'uncertain' have been grouped together and labelled 'not dead'. The table below lists the percentages, and the graphs on the next page present the same information visually.

Table 9: 2022 CRR trial monitoring results: % 'Not Dead'

Site	Eucaluptus		Acacia		Dodonaea	
	Local	Admix	Local	Admix	Local	Admix
Main A	98%	95%	98%	93%	91%	86%
Main B	95%	92%	87%	90%	67%	57%
S1	76%	71%	48%	24%	14%	0%
S2	95%	86%	81%	76%	N/A	N/A
S3	100%	100%	100%	100%	81%	100%
S4	86%	95%	N/A	N/A	10%	0%
S5	81%	90%	38%	71%	5%	29%
S6	N/A	N/A	100%	100%	100%	100%

These results show that, as at the end of 2022 when the tubestock had been in the ground for 18 months, there was no real difference between the survival of tube stock grown from local and non-local (or 'Admixture') seed.

Our conclusion at this point is that the YAN nurseries should continue to grow Climate Ready plants with Admix provenancing for distribution to their members and the general public. After 18 months, plants grown from non-local seed have initial establishment similar to plants from local provenancing.

The trial hosts will be asked to keep monitoring for another few years. As well as plant survival, they may be asked to report on evidence of flowering, suckering or seeding, as other important milestones after survival.

It was noted across a number of the trial sites that the Eucalypts have had the strongest survival, followed by the Acacias, followed by the Dondonaeas. The Dondonaeas have not done well in the wet conditions of the past few wet seasons, though it was noted that when planted on a well-drained ridge (e.g., supporting site 6), they have survived well.

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