Department of Environment and Conservation

Information Sheet 71 / 2013
Science Division

Climate-resilient revegetation of multi-use landscapes: adaptation to climate in widespread eucalypt species

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Background

Multi-million dollar investments in landscape restoration and carbon farming will need to consider climate change. The long term success of these plantings depends on the climate resilience of the species chosen. Until recently there has been a strong focus on sourcing seeds from local plant populations for revegetation and restoration. In a changing climate this may no longer be desirable because local populations that are highly adapted to past or present climatic conditions may lack the capacity to cope with a changing climate. Wide-spread species may provide the answer as they grow under a range of climatic conditions, and may therefore improve the climate resilience of restored ecosystems.

Species can achieve wide distribution via two main mechanisms; (1) by diverging into a series of specialised populations each specifically adapted to local conditions; and/or (2) through high phenotypic plasticity, the ability of individuals to adjust functionally to a range of environmental conditions including local climatic change. The extent to which each population is specialised or plastic in relation to climate will determine the seed-sourcing strategy required for optimal restoration outcomes under a changing climate (Figure 1).

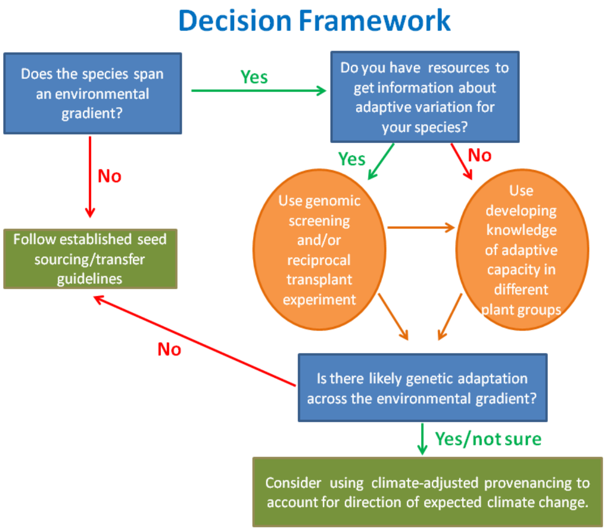

Figure 1: Flow diagram illustrating the decision making framework for choice of germplasm for environmental plantings

Objectives

We took a genomic approach to investigate adaptive variation across climatic gradients in two wide-spread *Eucalyptus* species (*E. tricarpa* and *E. salubris*). This was achieved by analysing and comparing both genetic variation and functional traits (e.g. leaf size and thickness) for each species along climatic gradients to test the following hypotheses:

1. Widespread species, having evolved under highly variable environments, retain high potential to adjust to environmental change within the gene pool of local populations or individuals (phenotypic plasticity). If this is the case, then genetic material sourced from local populations will have tolerance to changing climatic conditions.
2. Widespread species, having evolved across wide ecological gradients, comprise a suite of locally adapted sub-populations. If this is the case, then genetic material for environmental plantings should be sourced from potentially resilient populations that are already adapted to potential future environmental conditions.

Eucalyptus salubris at Queen Victoria Springs

Table 1. Climate data for *Eucalyptus* material used in this study.

MAP – mean annual precipitation; MAT – mean annual temperature

Species	Distribution	Climate Gradient	
E. tricarpa	Southeastern Australia	Central Goldfields 460 mm MAP	East Gippsland 1020 mm MAP
E. tricarpa	Southeastern Australia	Common garden 470 mm MAP	Common garden 840 mm MAP
E. salubris	Southwestern Australia	200 mm MAP 26 °C MAT	400 mm MAP 21 °C MAT

Findings

There is good evidence in both species for plastic response as well as genetic adaptation to climate. This indicates that widespread eucalypts can utilise a combination of both mechanisms to adapt to variation in climate.

Functional traits

- The *E. tricarpa* common garden data revealed high plasticity in most of the measured functional traits, particularly in water use efficiency and leaf density.
- In *E. salubris*, most functional traits showed little variation across the climate gradient, in particular leaf morphology appeared not to respond to climate in this study.
- Water use efficiency appeared highly plastic in both species, meaning that individuals are able to adjust to drier or wetter conditions.

Genome scans

- In both species, populations separated by distance also showed genetic differences, indicating genetic variation among populations of each species.
- Evidence of genetically based functional adaptation to climate was found in *E. tricarpa* through correlation of an 'adaptive genetic index' with many climatic variables, soil variables and some functional traits.
- In both species, particular genetic markers were correlated with climatic variables, and some were also correlated with functional traits, including plasticity of particular traits. This provides further evidence that particular regions of the genome relating to functional responses may be under selection in relation to climate.
- Markers potentially responsible for climate adaptation appear to be common to both species, suggesting that some mechanisms of climate adaptation might be conserved across species.

Management Implications

These findings highlight the complex nature of climate adaptation. Both study species showed evidence of a mixture of some genetic adaptation to local conditions, as well as capacity for plastic responses. Widespread eucalypts are therefore likely to be able to adjust to a changing climate to some extent, but selection of seed sources to match projected climate changes may confer greater climate resilience in environmental plantings. We recommend a strategy of 'climate-adjusted provenancing' with seed sources biased toward the direction of predicted climatic change (Figure 2).

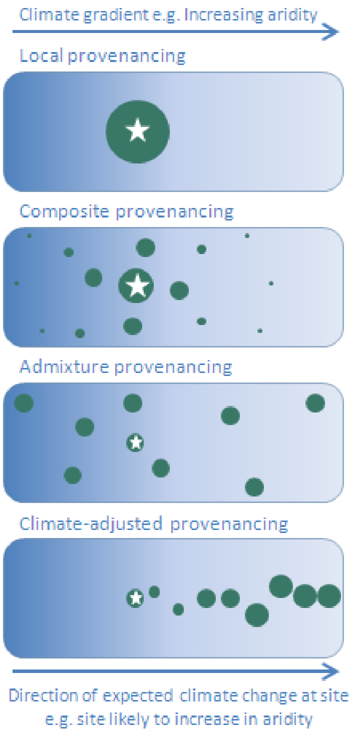

Figure 2: Illustrations of various provenancing strategies for revegetation. Star indicates site to be revegetated, green circles represent native populations used as germplasm sources. Circle size indicates the relative quantities of germplasm included from each population for use at the revegetation site.

The National Climate Change Adaptation Research Facility funded this study.

Produced and published by the Science Division, Department of Environment and Conservation, Western Australia,
Locked Bag 104, Bentley Delivery Centre, WA 6983