

Navigating forest dieback and climate succession:

Practical guidance for forest managers

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Acknowledgement of Aboriginal culture

We acknowledge and pay respect to the Traditional Owners and Custodians of the lands and forests across Australia. Aboriginal peoples have maintained deep and enduring relationships with forest landscapes for tens of thousands of years. These connections are woven into cultural identity, spiritual practice, law, and daily life, and continue to shape the stewardship and understanding of Country. Forests are far more than ecological systems; they are living cultural landscapes, integral to the stories, knowledge, and wellbeing of Aboriginal communities. The management, use, and protection of forests have always been guided by sophisticated systems of observation, adaptation, and care, passed down through countless generations. As we confront unprecedented climatic changes and ecological challenges, it is important to recognise that while the projected climatic conditions may have no direct historical analogue, Aboriginal cultures have successfully navigated dramatic environmental shifts before. Their resilience, adaptability, and custodianship offer invaluable lessons for contemporary forest management. We honour the wisdom, experience, and ongoing contributions of Aboriginal peoples in caring for forests and Country. We commit to working in partnership, listening, and learning from Aboriginal knowledge systems as we seek to adapt and safeguard forest landscapes for future generations.

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Executive Summary

Australian forests and woodlands are undergoing rapid change due to climate-driven dieback, increased tree mortality, and ecological succession. Traditional management approaches, based on stability and predictable risks, are no longer sufficient for these emerging threats. This guidance provides practical tools and strategies for forest managers, policymakers, and stakeholders to adapt planning and interventions. It draws on recent research, case studies, and policy frameworks to offer recommendations for safeguarding forest values and supporting adaptive decision-making.

Key themes:

- **Climate Drivers:** Rising temperatures, drought, extreme weather, and pests are now the main causes of tree mortality and dieback, leading to unpredictable changes in forest composition.
- **Management Challenges:** Managers must shift from static models to adaptive frameworks that use risk assessment, scenario planning, and regular review.
- **Barriers and Solutions:** Overcoming institutional inertia and resource constraints requires transparent communication and inclusive participation.
- **Decision Support:** Frameworks such as Resist–Accept–Direct (RAD) and rapid risk assessment protocols can help prioritise interventions.
- **Collaboration:** Cross-sector coordination and participation in networks like the Dieback and Climate Succession Network (DCSN) accelerate learning and improve outcomes.

Recommendations:

- Regularly update management plans to reflect current climate risks.
- Use value-based risk assessment to prioritise forest values.
- Implement a hierarchy of controls to reduce risk and enhance resilience.
- Monitor and evaluate interventions, sharing lessons learned.
- Engage with research institutions and collaborative networks for the latest tools and expertise.

This document is a living resource, open to ongoing feedback and revision, supporting managers in navigating uncertainty and securing the long-term health of Australia's forests.

Introduction

Australia's forests and woodlands are entering a period of rapid ecological change, driven primarily by the impacts of climate change. The landscape is shifting from one of relative stability to one marked by uncertainty, novel threats, and complex interactions between climate, disturbance, and forest health. This means that forest managers must reconsider established approaches and assumptions in the light of new evidence and emerging risks.

Recent years have seen a marked increase in tree mortality and dieback events, with climate factors such as rising temperatures, prolonged droughts, and extreme weather now recognised as the dominant drivers. These changes are not only altering the composition and function of forest ecosystems but also challenging the effectiveness of traditional management strategies. As a result, managers must now navigate dynamic environments where the boundaries between natural processes and maladaptive responses are increasingly blurred.

This guidance document responds to these challenges by translating current research, policy developments, and practical experience into actionable tools and frameworks. It is designed to support forest managers, policymakers, and stakeholders as they adapt planning and interventions to safeguard forest values and ecosystem services. The following chapters attempt a plain-English overview of dieback and climate succession, review the evolving context for forest management, and introduce adaptive planning approaches suited to the realities of climate-driven change.

Throughout, the emphasis is on practical, evidence-based strategies that can be tailored to diverse management contexts. By fostering collaboration, encouraging ongoing learning, and promoting transparent decision-making, this document aims to equip managers with the resources needed to respond effectively to uncertainty and secure the long-term health of Australia's forests.

Purpose of the Document

This guidance document is designed to support forest managers, policymakers, and stakeholders in responding to the complex challenges posed by climate-induced dieback and ecological succession in Australian forests and woodlands. It translates current research, policy developments, and practical experience into actionable tools, frameworks, and recommendations that can be tailored to diverse management contexts.

How to Use This Document:

- **Reference Tool:** Use this document as a reference for understanding the drivers, impacts, and management options for dieback and climate succession. Key concepts and frameworks are explained in plain English, with technical detail available in appendices.
- **Decision Support:** Apply the risk assessment methods, adaptive management frameworks, and intervention hierarchies to inform planning, prioritisation, and implementation of management actions.
- **Practical Guidance:** Follow the step-by-step checklists, case studies, and decision aids to guide adaptive planning, stakeholder engagement, and monitoring.
- **Collaboration:** Use the document to facilitate cross-sector coordination, stakeholder participation, and knowledge sharing, including engagement with networks such as the Dieback and Climate Succession Network (DCSN).
- **Living Document:** Treat this guidance as a living, working document, open to ongoing feedback, revision, and adaptation as new information, evidence, and policy emerge.

Who Should Use This Document:

- Forest managers and operational staff in government, private, and community-managed forests.
- Policymakers and planners developing or revising management plans.
- Researchers, restoration practitioners, and NGOs working on forest adaptation.
- Stakeholders and community members engaged in forest stewardship and decision-making.

Document Structure:

- The guidance is organised to move from context and definitions, through analysis of drivers and trends, to practical management frameworks and interventions.
- Technical details, worked examples, and legislative references are provided in appendices for deeper exploration.

1. Understanding Dieback and Climate Succession

1.1 Defining Dieback and Climate Succession

Trees are long-lived woody plants that underpin the structure and function of forest and woodland ecosystems. Many Australian species persist for centuries, with some woodlands requiring more than 150 years to reach maturity¹. The longevity of mature trees reflects the outcomes of a natural filtering process during stand development, where only individuals well-suited to local conditions, by virtue of establishment timing, landscape position, and genetic traits, survive.

Tree survival depends on maintaining a positive carbon balance under prevailing climate and disturbance regimes. In mature Eucalyptus forests and woodlands, this longevity is further supported by traits that enable recovery from damage, notably epicormic resprouting (regrowth from buds in thickened branches) and basal resprouting (regrowth from lignotuber bud banks²).

Forest dieback

Dieback refers to atypical, often large-scale declines in tree health and survival, which may occur suddenly or gradually across stands or landscapes. Historically, background mortality in mature Eucalyptus forests has been exceptionally low, typically less than 1% per year^{3–5}. Large-scale dieback events, therefore, signal rare or severe disturbances and may indicate environmental degradation or climate-driven shifts in habitat suitability.

Under climate change, forest decline is increasingly attributed to the interaction of carbon starvation (depletion of metabolic reserves), hydraulic failure (dehydration and xylem dysfunction), pest and disease pressures, and the intensity, duration, and frequency of disturbance events⁶.

In Australian forests hydraulic failure is more closely linked to canopy collapse than

to whole-plant death^{7,8}. Recovery from tissue damage is strongly influenced by the location and resilience of meristematic buds, which enable resprouting after disturbance^{9,10} (Figure 1), and moisture availability during resprouting periods.

In eucalypts, whole-plant mortality often results from compound stressors, such as drought combined with insect outbreaks or repeated disturbances such as drought and high severity fire in close succession, which likely deplete metabolic (carbon) reserves^{11–15}.

Climate succession

Climate change intensifies these challenges, driving higher temperatures, increased aridity, and more frequent droughts, fires, heatwaves, and insect outbreaks^{16–24}. While dieback has always occurred at some background frequency, recent events increasingly reflect responses to novel climate stressors. The global rise in forest and vegetation decline has significant implications for biodiversity, ecosystem structure, and function^{25–29}.

Changing abiotic conditions affect species differently; some may remain unaffected, others may be poorly adapted, while some may benefit^{30,31}. This leads to uneven impacts and a shifting balance of growth, survival, and competition within forest communities³².

Climate succession refers to the gradual, often unpredictable, adjustment of communities to novel climate pressures. In this context, large-scale dieback is expected and may signal instability or local maladaptation. As a result, it is becoming increasingly complex to distinguish whether dieback reflects natural cyclical change or the onset of climate-driven succession and community disruption.

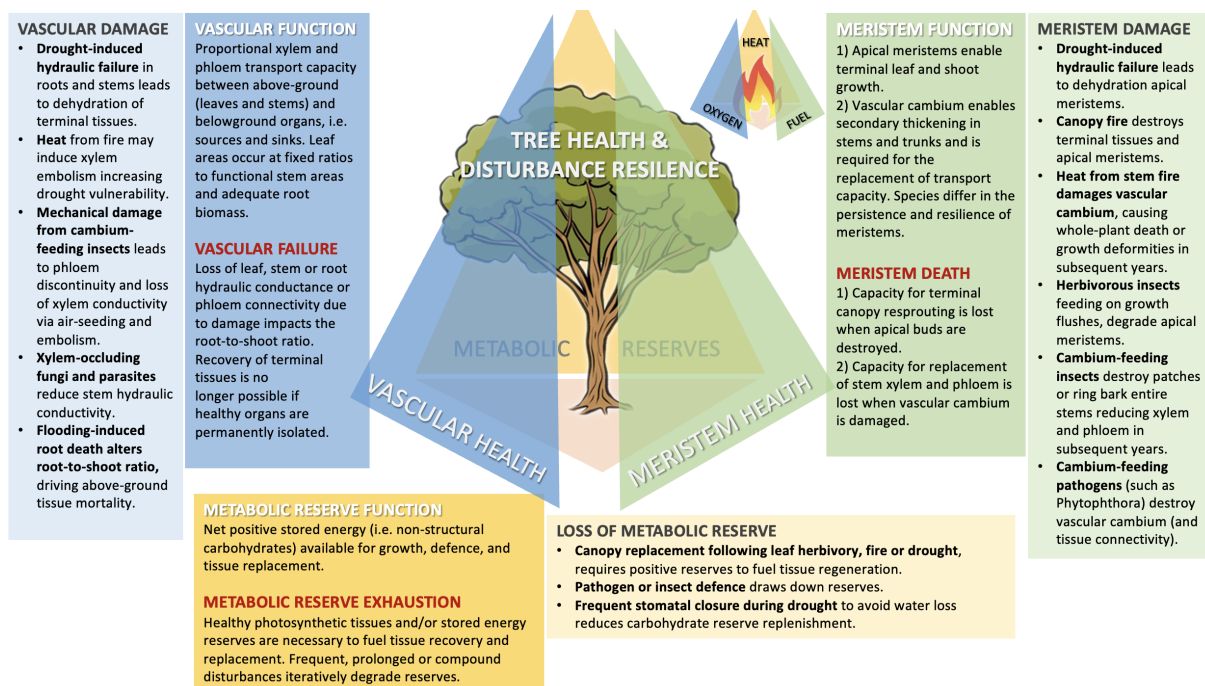


Figure 1. Analogous to a fire tetrahedron, this model illustrates the key elements required for tree health and resilience to disturbance: vascular function, meristem function, and positive metabolic reserves^{2,6}. Adaptive traits, such as epicormic buds and reserve tissues, enhance resilience to whole-plant mortality and are present in approximately 80% of Australian plant species^{2,10}. These traits underpin distinct responses to stressors that may otherwise cause whole-plant mortality in other regions³³.

1.2 Drivers of Change

Summary

Climate change is intensifying stress on forests through higher temperatures, more frequent droughts, increased fire risk, and greater insect and herbivore pressures. These factors interact to drive dieback and climate succession.

Key Drivers and Mechanisms

1. Atmospheric Drying and Vapour Pressure Deficit (VPD)

As temperatures rise, the atmosphere's capacity to hold water increases, intensifying its drying power—measured as vapour pressure deficit, as illustrated in Figure 2. Even when rainfall remains unchanged, higher VPD draws more water from vegetation, increasing drought stress. This effect is amplified during heatwaves

and droughts, resulting in more severe and prolonged water deficits, including elevated nighttime water loss^{34–39}.

2. Drought, Fire and Water Stress

Reduced plant water content not only increases the risk and severity of fire but also limits the capacity of trees to recover from disturbance^{24,34,40}. Droughts and heatwaves can cause xylem embolism, air blockages in water transport tissues within trees, leading to hydraulic failure in vulnerable species, causing canopy collapse or whole-plant mortality^{22,41,42}. In many Australian forests, hydraulic failure is more often linked to canopy collapse than to whole-tree death⁷. Mortality occurs in species with limited resprouting capacity and through compounding stressors like insect attack and trophic cascades^{6,43}.

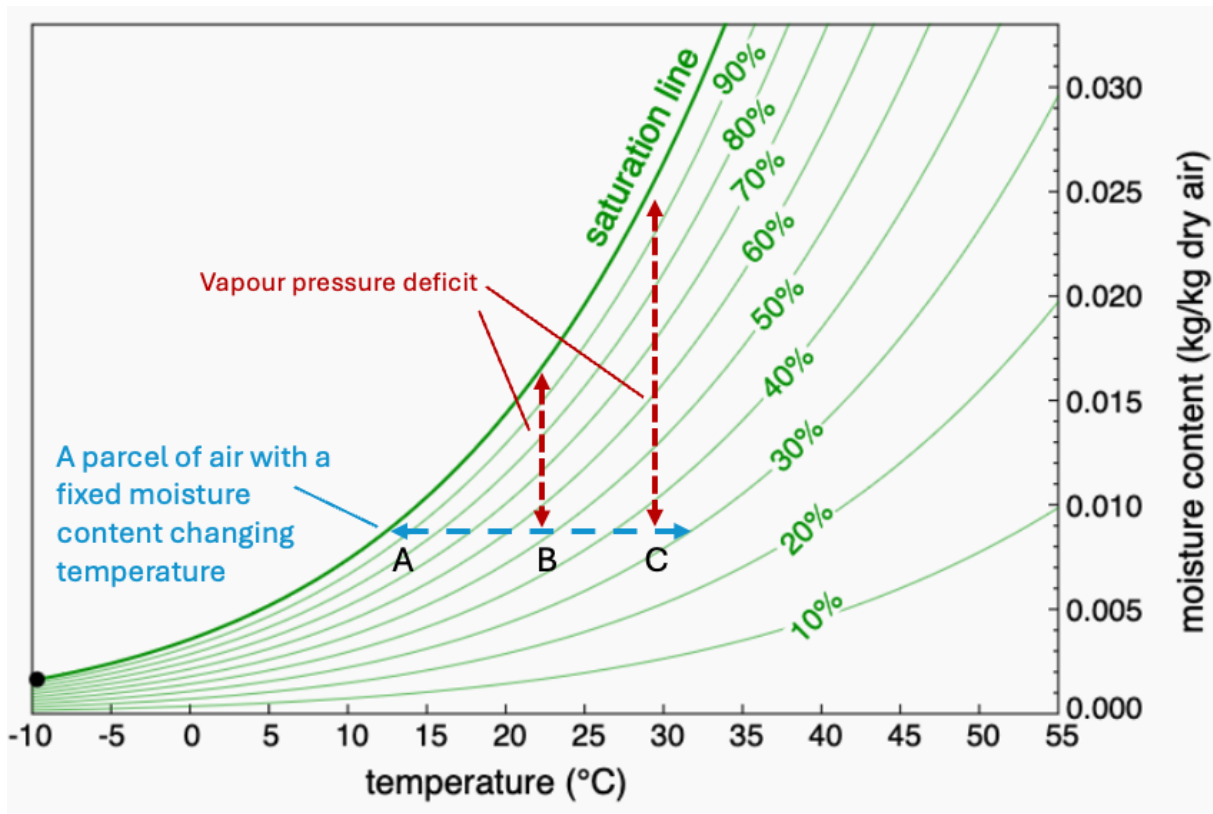


Figure 2. As global temperatures rise, the air can hold more water, which increases its drying power. When the gap between how much moisture the air could hold (saturation) and how much it holds grows larger—known as vapour pressure deficit—the air draws more water from everything around it, including plants and soil. This stronger drying effect means more water is pulled from the earth’s surface. Figure adapted from the [Department of Chemical and Biological Engineering, University of Colorado Boulder](#).

3. Insect Herbivory Pressures

Warmer temperatures speed up the growth, reproduction, and survival of insects, leading to more frequent and severe outbreaks^{44–50}. Drought weakens plant defences and concentrates nutrients in leaves, making them even more attractive to insects^{19,51–53}. When Eucalypts are stressed, they respond by producing new growth. This regrowth is especially appealing to many herbivores accelerating insect outbreaks^{54–56}. When drought, insect outbreaks, and repeated disturbances occur together, they can quickly drain a tree’s energy reserves, increasing the risk of whole-plant death.

4. Compound and Cascading Stressors

Dieback events are rarely driven by a single factor. Instead, they often result from the interaction of multiple stressors, climate extremes, pest outbreaks, and repeated disturbances, which together can overwhelm the resilience mechanisms of even long-lived species^{15,57}. These compound effects are increasingly common under climate change and can lead to rapid, large-scale shifts in forest structure and function^{58–60}.

5. Climate Succession and Community Instability

Changing abiotic conditions affect species differently, some remain unaffected, others are poorly adapted, and some may benefit, resulting in uneven impacts and a shifting balance of growth, survival, and competition within communities³¹. Climate succession refers to

the gradual, often unpredictable adjustment of communities to novel climate pressures. This could include local collapse or fragmentation of existing communities^{61–63}. Large-scale dieback may signal instability or local maladaptation, making it increasingly difficult to distinguish between natural cyclical change and the onset of climate-driven succession.

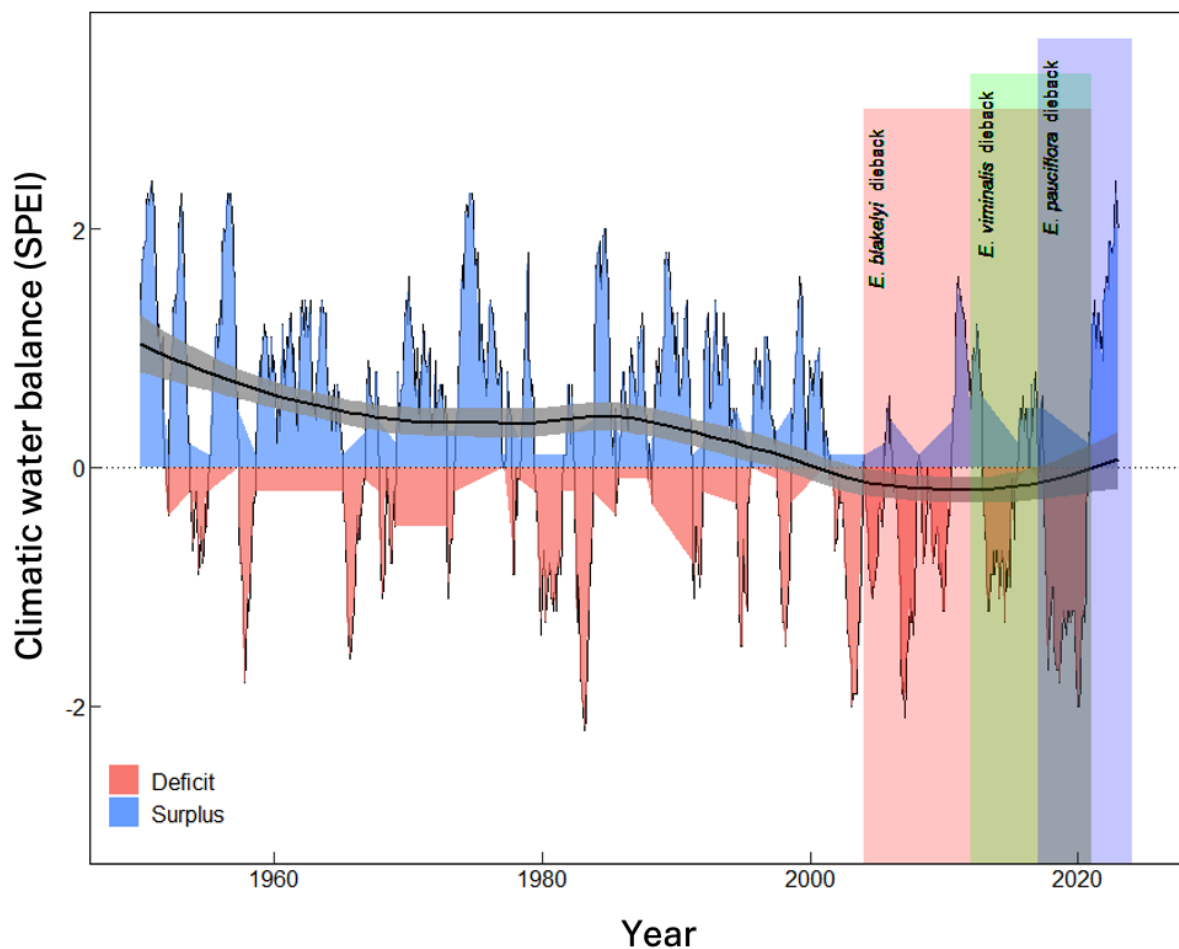


Figure 3. Declining climatic water balance quantified using the standardised precipitation-evapotranspiration index (SPEI). Data are a 12-month rolling average for the Monaro Tablelands, NSW, obtained from the [SPEI Global Drought Monitor](#). SPEI values lower than 0 indicate periods where evapotranspiration is greater than precipitation⁶⁴. The approximate timing of three regional-scale woodland dieback events has been overlayed for reference: pink, *E. blakelyi*¹², green, *E. viminalis*⁵⁴; blue, *E. pauciflora*¹¹.

1.3 Predicted Vegetation Trends

Summary

Dieback and climate succession are expected to significantly alter the condition, composition, and values of forests. The impacts will vary by location, microclimate and species. Forest managers should expect the key trends outlined below. Importantly, these trends may unfold both simultaneously and in sequence.

1. Large-scale transformation

All ecosystems will face pressure from rising temperatures. Communities at the margins of their distribution and specialists are especially vulnerable^{21,24,65}.

Examples: Subalpine snow gum woodlands in the Australian Alps and Ash forests in Victoria have experienced widespread dieback and shifts in community structure due to warming and repeated fires^{11,23,66}. In south eastern Australia, severe fire and drought conditions can nullify the protective refugia effects of topography and lower fuel loads⁶⁷.

2. Sudden and gradual declines in condition

Both ongoing background change and extreme events can trigger unexpected declines in vegetation condition^{68,69}.

Examples: Regional climatic water deficits between 2000-2020 in the Monaro tableland lead to gradual and local declines of several key co-dominant forest species, including Ribbon gum, Snow gum and Blakely's Red gum^{11,12,54,70,71}. The 2019-20 Black Summer bushfires and droughts caused rapid, large-scale loss of forest cover across many forest ecosystems and communities^{24,65,72}. Consistent with global trends, census surveys across multiple Australian forest types have found increasing annual rates of background tree mortality⁶⁹.

3. Delayed mortality from compound stressors

Repeated disturbances, such as drought followed by insect outbreaks, can deplete trees' carbohydrate reserves, leading to long-term or irreversible impacts.

Examples: Chronic droughts stress in *Eucalyptus marginata* and *Corymbia calophylla* in southwestern Australia are associated with increased mortality and dieback during subsequent short-term stressors like heatwaves⁵⁹. In southern temperate forests, higher rates of fire-induced mortality in juveniles are seen in multiple Eucalypt species, when previously challenged by severe drought⁷³.

4. Population fragmentation

Shifts in climate suitability will cause species to retract and fragment, with some persisting only in protected microhabitats.

Examples: Subalpine snow gum woodlands in the Snowy Mountains have been impacted by wood-borer pressure in their lower warmer elevations, but healthy mature stands remain unaffected at the highest elevations¹¹. In the Clare Valley, SA, dieback from drought stress has fragmented local Stingy Bark stands by north-south aspect⁷⁴.

5. Declining native diversity

The combined effects of increasing disturbance regimes, dynamic and homogenous structural vegetation, altered invertebrate and pollination dynamics are predicted to lead to simplification of many local systems⁷⁵.

Example: Local extinction of understory species in Karri forests of southwestern Australia following severe fires due to a higher proportion of seed bank mortality⁷⁶.

6. Insect and disease outbreaks

Drought weakens plant defences, favouring pest outbreaks. Warmer conditions also speed up insect reproduction and spread.

Examples: Bell miner-associated dieback (BMAD) in coastal NSW and Blakely's Red Gum Dieback on the Monaro tableland are linked to psyllid outbreaks following drought^{51,54}. While wood-borer outbreaks associated with heatwaves and drought have caused extensive dieback in WA, NSW and QLD^{11,52,53}.

7. Demographic skew toward younger and even-aged cohorts

Long-lived species that require infrequent disturbance, such as snow gum and mountain ash, may fail to regenerate, resulting in stands dominated by young trees.

Examples: Repeated fires across large sections of the Australian Alps have left stands increasingly dominated by younger trees, and leaving only 1% of mature snow-gum stands remaining⁶⁶. Ash forests in Victoria now have fewer mature trees and are increasingly dominated by younger, even-aged regrowth⁷⁷.

8. Maladapted trait-based population and community refiltering

Species with traits that confer resilience - such as epicormic resprouting, bark thickness, time to maturity or drought tolerance - will become more common, while others decline⁷⁸.

Examples: The persistence of fire sensitive, obligate-seeder species like Ash in temperate Australia are threatened by the recurrent fire intervals of <20 years^{23,77}. Epicormic resprouting species, generally resilient to fires, may also fail to regenerate when challenged with short fire intervals^{79,80}.

9. Reduced regeneration and recruitment

Changing climate conditions may limit the windows for successful seedling establishment.

Example: Recurrent fires within a period of 20 years lead to failure of ash species' seed bank, as strands fail to reach reproductive maturity

within the return interval^{23,77,81}.

10. Community reassembly

Without intervention, climatic refiltering of local species pools will drive short-term reassembly, favouring fast-growing, mobile, disturbance-tolerant species.

Example: In Wilson's Prom, repeated short interval fires can lead to conversion of even resprouting Eucalypt forests to Acacia-dominated shrublands⁸².

11. Emergence of novel communities

Fragmentation and species drift will likely produce ecosystems with no historical analogues, risking the loss of specialised species^{75,83,84}.

Example: The predicted transition of temperate grassy woodlands to those with reduced diversity and dominance by species with coloniser (weedy traits)⁷⁵.

12. Increased invasive species pressure

Frequent disturbances favour invasive colonisers, increasing risks to native biodiversity.

Examples: The expanded distributions of invasive species such as African lovegrass and Buffel grass, favoured by pastoralists for their drought resilience, but outcompeting native species.^{85,86}

Note, although the trends above are listed individually, multiple changes often occur together within the same landscape or forest stand. For example, a site may simultaneously experience large-scale transformation, fragmentation, and increased invasive species pressure. Under climate change, overlapping and interacting impacts are common, and managers should expect complex, compounding changes that may amplify risks or create novel ecosystem dynamics.

2. Rethinking Forest Management

2.1 Challenging Management Assumptions

Summary

Climate change is rapidly reshaping the ecological, institutional, and operational context of forest management. The pace and unpredictability of these changes are challenging long-standing assumptions that have traditionally guided practice. Increasingly, experts advocate for a shift from static, preservation-focused models to adaptive approaches that can respond to novel risks and uncertain futures^{87–101}.

This section examines the foundational premises of current forest management frameworks, many of which were developed during more stable periods, and highlights the need for reassessment considering climate-driven instability and shifting species distributions. Without such reflection, management actions risk becoming misaligned with an increasingly dynamic environment.

Reviewing assumptions

Forest managers should take time to critically examine their own assumptions, as well as those held by their teams and stakeholders. This reflective process fosters a shared understanding of the challenges and opportunities posed by dieback and climate succession.

Open discussion and documentation of beliefs about ecosystem stability, risk, values, and the role of management can help surface hidden barriers, clarify areas of agreement and disagreement, and identify where further engagement or capacity-building is needed. This process builds trust and transparency, while also helping teams anticipate and address sources of resistance. Ultimately, it strengthens the effectiveness and resilience of adaptation planning and implementation.

To support a structured and actionable review of forest management assumptions, they are grouped into four thematic categories:

Ecological Dynamics – Beliefs about species stability, succession, and disturbance regimes.

Risk and Uncertainty – Perceptions of predictability, thresholds, and acceptable levels of change.

Values and Objectives – Norms around conservation, cultural significance, and ecosystem services.

Management Roles – Expectations of intervention, control, and stewardship responsibilities.

[Appendix A](#) provides a framework of forest management assumptions to support a structured review either as an individual or in a group. The framework provides for each premise its original assumption, the emerging challenge posed by climate change, and a real-world example to illustrate its implications.

2.2 Implications for Forest Management

Summary

Reassessing the foundational assumptions of forest management has far-reaching implications. As climate change continues to destabilise ecological systems, forest managers will increasingly need to move beyond technical adjustments and reorient goals, tools, governance, engagement, and funding strategies.

This section outlines key shifts in practice and provides actionable guidance to support adaptation in the face of climate-induced dieback and climate succession.

Key Shifts and Practical Guidance

1. Shift from Composition to Function

- **Challenge:** Local historical plant communities may no longer be viable under climate instability, and therefore, community composition may no longer be a reliable indicator of other embedded values.
- **Action:** Prioritise ecological functions such as carbon storage, habitat provision, water regulation, and resilience, over restoring specific species compositions of communities.

Example: Replace efforts to restore alpine woodland with a drought-tolerant assemblage that delivers equivalent ecosystem services.

2. Embrace Adaptive, Flexible Planning

- **Challenge:** Fixed, long-term plans are less effective in unpredictable environments.
- **Action:** Adopt adaptive frameworks with built-in monitoring, scenario planning, and decision points for reassessment.

Example: Design management plans with thresholds and decision triggers and shorter review cycles.

3. Reframe Risk Management

- **Challenge:** Climate risks cannot be fully mitigated through regulation alone.
- **Action:** Use strategies such as bet-hedging, redundancy, and diversification to reduce vulnerability.

Example: Plant mixed-species assemblages with varied drought tolerance and reproductive traits to buffer against extremes.

4. Strategic Resource Allocation

- **Challenge:** Resource constraints will intensify under climate pressure.
- **Action:** Apply triage-style approaches to focus efforts where success is most likely, or where forest values are irreplaceable.

Example: Prioritise protection of remnant mature vegetation in climate refugia over broad-scale restoration in degraded areas.

5. Redesign Policy Frameworks

- **Challenge:** Existing tools often assume ecological stability and controllable risks.
- **Action:** Review and retrofit policy instruments to enable timely, flexible, and context-sensitive responses.

Example: Introduce reforms that enable novel ecosystems and the timely adaptive management of forests.

6. Coordinate Across Sectors

- **Challenge:** Climate impacts transcend tenure boundaries and institutional silos.
- **Action:** Align strategies across public, private, and community-managed lands.

Example: Coordinate fire management, pest control, and restoration efforts across jurisdictions to avoid conflicting outcomes.

7. Engage and Empower Stakeholders

- **Challenge:** Adaptation requires broad-based support and stewardship.
- **Action:** Use upstream engagement, transparent communication, inclusive decision-making, and capacity-building to build trust and shared ownership.

Example: Involve local communities in adaptation planning to align ecological goals with social values.

8. Anticipate Novel Ecosystems

- **Challenge:** Assemblages with no historical analogue are increasingly likely.
- **Action:** Recognise novelty as a legitimate outcome and develop tools to assess, monitor, and guide these systems toward functional resilience.

Example: Support mixed-species woodlands dominated by disturbance-tolerant colonisers if they maintain critical ecosystem services.

9. Resource Management Adaptation

- **Challenge:** Traditional funding models may not accommodate adaptive, function-based approaches.
- **Action:** Advocate for revised funding criteria that support flexible, outcome-focused projects and rapid response.

Example: Enable funding for adaptive management, stakeholder engagement, and interventions in novel ecosystems, not just historical restoration.

Note, managers should use these strategic shifts to guide planning, resource allocation, and stakeholder engagement. Regular review and updating of management approaches is essential as new information and local data become available.

3. Rethinking Forest Management Planning

3.1 Adaptation Planning Principles

3.1.1. The Importance of Management Planning

Summary

Forests are managed under a range of regulatory and management frameworks, e.g., National Parks, State forests, Crown land, Local Government reserves, etc. It is beyond the scope of this document to address each management context individually. However, almost all require the production of a management plan that translates policy into action.

Proactive and agile management planning processes are essential for responding to dieback and other climate-driven risks. To ensure that management responses are effective and enduring, it is imperative that they are supported by an appropriate management plan. Reviewing and adapting the management plan to enable interventions that support adaptation will increasingly become a priority for forest managers¹⁰⁰.

Key Points for Managers

- **Management plans are the main tools for translating priorities into action.** In Australia, these plans are informed by legislation, policy, stakeholder input, and local values.
- **Many existing plans are static and based on outdated assumptions of ecological stability and self-regeneration.** Some management plans have remained unchanged since their creation. They may not be equipped to respond to the accelerating risks posed by climate change and dieback.
- **Passive protection strategies are increasingly insufficient.** In a changing environment, inaction can lead to irreversible degradation, particularly when climate pressures and dieback events compromise ecosystem resilience.

Practical Guidance for Management Planning

1. **Make Plans Adaptive and Proactive** Move away from static, one-off plans. Design management plans that can be updated regularly in response to changing ecological conditions and new information. Include clear monitoring thresholds and decision points that trigger reassessment and action.
2. **Address Diverse Impacts Across Landscapes** Recognise that climate change and dieback affect different areas in different ways. Plans should be flexible enough to address heterogeneous impacts and prioritise actions where they are most needed.
3. **Enable Innovation and Trialling of Solutions** Support the development and testing of new approaches, tools, and treatments. Encourage learning from both successes and failures.
4. **Maximise Co-Benefits for Biodiversity, Culture, and Communities** Design plans to deliver multiple benefits, including ecological resilience, cultural values, and community wellbeing.
5. **Establish Transparent Processes for Managing Trade-offs** Clearly outline how trade-offs between competing forest values (e.g., biodiversity vs. fire risk) will be managed. Use summary tables and decision aids to support transparent decision-making.

6. **Promote Inclusive Participation** Engage stakeholders, including local government, Indigenous communities, NGOs, and the public, in planning and decision-making. Build trust and long-term stewardship through transparent communication and capacity-building.
 7. **Coordinate Efforts Across Jurisdictions and Governance Levels** Facilitate collaboration across agencies, tenures, and sectors. Align actions to avoid conflicting outcomes and maximise impact.
 8. **Plan for Transition and Restoration, Not Just Maintenance** Reframe disturbance impacts as opportunities for transition and stabilisation. Recognise degraded systems as potential sites for resilience-building, diversification, and ecological recovery.
- **Managers should expect overlapping impacts:** Drought, fire, insect outbreaks, and invasive species will interact, compounding stress and accelerating change across landscapes.
 - **No single trend will dominate:** Vegetation shortening, demographic skew, trait-based filtering, and the emergence of novel communities will occur together, often amplifying each other's effects.
 - **Adaptation requires holistic planning:** Because these trends are interconnected and simultaneous, management responses must be flexible and proactive. Strategies developed locally must be considered in light of larger spatial scales and responses coordinated across tenures and ecological conditions. Managers must expect to face multiple challenges at once.
 - **Uncertainty is the new normal:** The pace and complexity of change mean that managers must anticipate surprises and be prepared to pivot strategies as new information emerges.

Take-Home Messages:

- **Multiple changes may unfold at the same time:** Forests are expected to experience large-scale transformation, sudden and gradual declines, delayed mortality, population fragmentation, and shifts in species composition, possibly concurrently.

3.1.2. Barriers to Adaptive Forest Management

Summary

Adapting forest management planning for an uncertain future is critical to safeguarding forest values and securing the provision of ecosystem services. Yet, changing established structures, processes and practices is inherently difficult and often met with resistance from institutions, stakeholders, and practitioners. Forest managers should expect resistance and develop strategies to overcome barriers to change.

Why Change Is Difficult

1. Institutional Inertia and Legacy Systems

- Forest management is governed by established structures, regulatory frameworks, and entrenched practices that favour continuity over change.
- Existing plans, funding models, and reporting requirements may actively discourage innovation and adaptation.

2. Psychological and Cultural Barriers

- Change can evoke grief for lost landscapes, resistance to abandoning familiar practices, and fear of uncertainty. Grief can result in denial, anger, blame, bargaining and depression; however, limiting degradation of forest values requires accepting the realities

of our current position^{102,103}.

- Practitioners may be reluctant to trial new approaches, especially when outcomes are uncertain or success cannot be guaranteed^{104,105}.

3. Complexity and Uncertainty

- Climate change introduces deep uncertainty about future conditions, making it difficult to set clear targets or predict outcomes.
- Decision-making under uncertainty requires new skills, tools, and mindsets—such as adaptive management, scenario planning, and risk triage.

4. Resource Constraints

- Adapting plans and practices often requires additional resources, expertise, and time.
- Funding models may favour traditional restoration over adaptive, function-based approaches, limiting the scope for innovation.

5. Resistance from Stakeholders

- Stakeholders may resist changes that threaten established interests, values, or roles.
- Building consensus for change requires transparent communication, inclusive participation, and capacity-building.

Practical Guidance for Overcoming Resistance and Enabling Change

1. Start with a Clear Rationale and Available Evidence

- Use local case studies, climate projections, monitoring data, and value-based risk assessments (Section 3.12) to demonstrate why change is necessary.
- Use the adaptation planning tools to demonstrate that a comprehensive analysis of the options underpins proposed changes.
- Reference key threatening process (KTP; Section 3.5) and national and state adaptation strategies to anchor reform proposals (Section 3.6).

2. Embed Adaptive Management Principles

- Design management plans should be treated as living documents, open to regular review and revision.
- Include clear monitoring thresholds, decision triggers, and feedback loops.

holders identify specific barriers (i.e., knowledge, rules or values) to adaptation within their context and develop targeted strategies to address them.

Steps:

1. Barrier Identification
2. Impact Assessment
3. Strategy Development
4. Action Planning
5. Reflection and Feedback

Overcoming Barriers to Managing Change

Forest managers should not underestimate the challenge of changing entrenched forest management policy and practice. Building consensus for change will require transparent communication, inclusive participation, and capacity-building. Despite the unfamiliarity of this new management challenge, the tools and processes presented in subsequent sections can improve management confidence, agency and strategy in this new management context.

Changes to forest management legislation and policy to address dieback and climate succession are likely to lag behind the need. In the interim, forest managers should consider utilising existing levers, such as key threatening process declarations and climate change adaptation strategies, to drive proposed changes to forest management plans.

Proposed Activity

Barrier Mapping and Strategy Planning Workshop

Objective:

A facilitated half-day workshop using the barrier framework outlined above. The aim is to help forest managers, their teams, and stake-

3.1.3. Futures-thinking Stakeholder Workshops

Summary

Futures-thinking workshops are structured scenario-based planning sessions that bring together a broad range of stakeholders to anticipate, plan for, and navigate multiple possible futures^{87,106–109}. These workshops are essential for developing management pathways that can mitigate perverse outcomes and build resilience in the face of climate-driven uncertainty^{105,108,110–112}.

Key elements of effective futures-thinking workshops:

- **Update the decision context:** Incorporate the latest data on current conditions and future climate projections.
- **Map potential futures:** Use state-and-transition models to collate a shared vision of all possible futures in a given location, visualise possible ecosystem trajectories and identify tipping points.
- **Re-evaluate values and goals:** Regularly review and clarify management priorities, especially for values at risk of irreversible change.
- **Develop trigger points:** Define clear thresholds for when to pivot management strategies.
- **Consider practical constraints:** Factor in current (and potential future) resourcing, feasibility, and operational realities.

Actionable recommendations for forest managers:

- **Engage a diverse group of stakeholders:** Include landholders, restoration NGOs, forestry managers, Traditional Owners, and government agencies at all relevant scales.
- **Facilitate transparent, iterative workshops:** Use plain language, encourage open discussion, and revisit scenarios as new information emerges.
- **Document and communicate outcomes:** Record strategies, barriers, and resource needs, and share findings with all participants.
- **Integrate workshop outputs into management plans:** Use insights to inform adaptive pathways, contingency planning, and prioritisation of actions.
- **Build social licence:** Foster trust, increase transparency and upstream support for adaptation decisions through participation and transparency.

Futures-thinking workshops are most effective when they are ongoing, adaptive, and embedded within broader management and policy frameworks^{88,107}. Their success depends on transdisciplinary participation, clear communication, patience, persistence and a willingness to adapt as conditions change.

3.2 Risk and Value Assessment in Planning

3.2.1. Revisiting Forest Values

Summary

Forest values are central to forest management planning. These values are enshrined in legislation and policy and guide decisions about what to protect, where to act, and how to prioritise competing objectives. Traditionally, these values have aligned, supporting biodiversity, ecosystem services, and cultural heritage. However, climate change and dieback are disrupting this alignment, creating new tensions that may require trade-offs. Managers should now assess each value individually for its vulnerability, adaptability, and potential for intervention.

Key Points for Managers

- Values are not equally resilient. Some are location-bound and fragile; others are restorable or trans-locatable.
- Traditional assumptions may no longer hold. For example, maintaining historical species composition may not be possible while preserving or restoring ecological function under new climatic conditions
- Management should shift from uniform protection to value-specific risk assessment. This includes evaluating each value's exposure to climate impacts and its amenability to stabilisation.

Checklist: Key Protected Forest Values

These values are referenced in legislation and management plans. They span species, habi-

tats, ecological processes, and cultural functions:

- Species
- Habitat
- Habitat suitability for threatened species
- Ecological communities and TECs
- Native and remnant vegetation
- Vegetation integrity
- Areas of outstanding biodiversity
- Soil conservation and nutrient cycling
- Water catchment protection
- Timber production and wilderness areas
- World/National heritage areas
- Cultural heritage sites and objects
- Recreation and ecosystem components

[Appendix A](#) details the Legislated Forest Values.

Action:

- Identify the protected forest values that apply to your management context.
- Consider whether there are conflicts between values, e.g., composition and function
- Consider whether all the values can be protected or restored with projected climate change.
- Is there a hierarchy of values? Are some more important than others?

3.2.2. Revisiting Risk Assessment

Summary:

Dieback and climate succession are reshaping the risk landscape for forest managers. Traditionally, risk management has focused on managing known impacts to stable ecological assets. Now, risks emerge unpredictably and independently of management actions. The new conditions require that the risks to forest values are reassessed.

Value-based climate risk assessment involves identifying priority values, assessing their vulnerability to climate impacts, and evaluating both the likelihood and severity of potential losses. By understanding which values are most at risk, managers can prioritise interventions, allocate resources efficiently, and develop adaptive strategies. This approach enables transparent decision-making, supports stakeholder engagement, and ensures that interventions are both defensible and effective, even under deep uncertainty.

Value-based risk assessment framework:

[Appendix C](#) details a step-by-step value-based risk assessment and mitigation framework for

dieback and climate succession. It can be applied proactively as part of adaptation planning or reactively following impacts.

Collaboration and Information Sharing

Dieback and climate succession occurs at the landscape scale and is not tenure specific. Further, translocation of climate-displaced species to future-climate suitable locations may require distances of hundreds of kilometres. Effective risk assessment and mitigation will require collaboration and coordination across agencies, tenures, and sectors.

Actionable Steps

- Review the risk assessment and mitigation framework at [Appendix C](#).
- Identify the appropriate scale for the risk assessment and mitigation planning process and who should be involved.
- Use collaborative platforms to facilitate the sharing of information, lessons learned and best practices.

3.2.3. Assessing Risk Tolerances

The risk assessment process will identify which forest values are most vulnerable to climate change. In considering how to respond, forest managers must evaluate their risk tolerance for each value. The importance of different forest values and risk tolerance will vary according to the management context, e.g., timber production, habitat conservation.

Is the current level of risk to the value acceptable?

Some forest values are at greater risk than others, and local impacts can be highly uneven. Some existing location specific values may be

indefensible in their current locations, while others may be restorable or trans-locatable. This asymmetry among values demands a more flexible and strategic approach to value protection.

Table 2 illustrates how some forest values, particularly those tied to location-specific composition or specialised taxa, may become indefensible under climate change projections. Others, such as ecological processes or the habitats of generalist species, may be more amenable to both restoration and translocation. Recognising these differences will become increasingly important in prioritising management interventions and allocating resources effectively.

Table 2: Asymmetry of Vulnerability Among Environmental Values

Limited Defensibility	Defensible	Restorable
- Existing composition - Existing extent / distribution - Locally specialised species or ecological communities - Existing vegetation structure and function - Habitat quality and suitability for highly specialised taxa	- Native vegetation - Soil resources - Wilderness - Non-living world (national and cultural heritage) - Catchment quality - Remnant vegetation - Pre-existing ecological character - Ecosystem processes (i.e., nutrient cycling) - Species' genetic diversity and evolutionary potential (ex-situ)	- Vegetation integrity (i.e., structure and function) - Ecosystem processes (i.e., nutrient cycling) - Habitat quality and suitability for generalist species - Net extent of species and communities (non-specialised taxa; ex-situ)

3.2.4. Risks associated with Management Actions

Summary

Given the high levels of uncertainty, both management action and inaction pose additional risks to forest values. Interventions may fail, produce unintended consequences, or become unsustainable over time. Forest managers should consider these secondary risks in selecting management interventions.

These secondary risks include:

- **Effectiveness** – Will the intervention achieve its intended outcome?
- **Longevity** – Will it remain viable under worsening conditions?
- **Off-target effects** – Could it negatively impact other values?
- **Establishment costs** – What is the cost per hectare to implement?
- **Ongoing costs** – What are the long-term maintenance requirements?
- **Social feasibility** – Will stakeholders and the public support it?



Effectiveness (evidence & scale of effect)	
>90%	
>50 – 90%	
<50%	
Unknown (or too hard to estimate)	
Positive co-benefits	
Definitely some	
Maybe some	
None	
Unknown (or too hard to estimate)	
Social feasibility	
High feasibility	
Moderate feasibility	
Low feasibility	
Unknown (or too hard to estimate)	
Risk of negative unintended consequences	
<1%	
>1 – 10%	
>10%	
Unknown (or too hard to estimate)	
Establishment cost	
<\$10 000/ha	
>\$10 000 - <\$100 000/ha	
>\$100 000/ha	
Unknown (or too hard to estimate)	
Total ongoing cost (20-year deployment)	
<\$10 000/ha	
>\$10 000 - <\$500 000/ha	
>\$500 000/ha	
Unknown (or too hard to estimate)	

Figure 4. A framework for assessing the secondary risks arising from management interventions. Reproduced from AdaptLog¹¹³.

Many climate-adaptive management interventions lack precedent, and uncertainty around secondary risks is unavoidable. Adaptive management frameworks must operate to iteratively adjust interventions based on feedback. Secondary risks apply to both active and passive interventions.

These risks can be mitigated by:

- Trialling and validating novel methods at small scales
- Updating predictions and projections regularly
- Engaging stakeholders and improving public understanding

- Coordinating across institutions and tenures to reduce duplication
- Investing in foundational knowledge (e.g., inventories, monitoring, modelling)

Where both action and inaction carry risk, diversifying strategies across different areas is important to hedge against uncertainty. Even well-informed strategies may not be sufficient to maintain current forest values under escalating climate pressure. Small-scale trials in lower-risk areas should ideally precede broader deployment. A transparent adaptive decision-making management process is required, including an understanding that not all interventions will succeed.

Categorising Risk Tolerances

Low tolerance for risk - Preference for conservative, low-risk interventions

Examples:

- Threatened species and ecological communities – Low margin for error.
- Soil erosion – Recovery takes centuries; tolerance is narrow.
- Genetic diversity – Often irreplaceable; loss should be minimised.
- Structural habitat in slow-growing ecosystems – Critical for fauna and ecosystem function
- Catchment quality – Essential for water security.

Medium tolerance for risk – Willingness to take measured risks to enhance objectives.

Examples:

- Widely distributed but climate-sensitive forests – May warrant trials of unvalidated interventions (e.g., ecological thinning, increased burn frequencies).

High Tolerance for risk - Greater openness to innovation and experimentation.

Examples:

- Highly degraded landscapes – Restoration may require bold experimentation with species mixes, including climate-adjusted provenances, broader genetic variation, or even out-of-area climate adjusted or displaced species.

3.2.5. Prioritising Forest Values

Summary

There is considerable uncertainty surrounding the risks posed by climate change. Some values are already experiencing impacts, while for others, the magnitude and trajectory of change remain unclear. Without proactively establishing a clear triage system, forest managers may lack a structured pathway for prioritising competing values, response times are delayed, and windows to act are missed.

Tiered Management

Tiered management is a form of adaptive planning that enables managers to pivot between priorities and interventions as conditions change, or thresholds are approached. This involves identifying cascading responses and framing decision-making triggers. The approach supports dynamic prioritisation across a hierarchy of values, controls, and trigger points, enabling strategic responses under resource constraints and ecological uncertainty.

Key considerations include:

In-Situ vs Ex-Situ Conservation

Managers must assess which values can be maintained in situ and which require ex-situ strategies, such as relocation to protected or climate-adjusted sites. As climates shift, some values may no longer be defensible in place.

Resourcing and Viability

Even if restoration is technically possible, it may be economically or logistically unviable under ongoing climate stress. Resource adequacy and investment feasibility must be weighed.

Transparency and Participation

Public expectations and ecological grief shape decisions. While grief is natural, planning must consider worst-case scenarios. Tools like scenario workshops and climate-pathway models support transparency and stakeholder engagement.

Disaster Planning and Coordination

Without worst-case scenario planning, responses are delayed. Australia's layered governance demands proactive, coordinated strategies to avoid conflicting priorities and delays¹¹⁴.

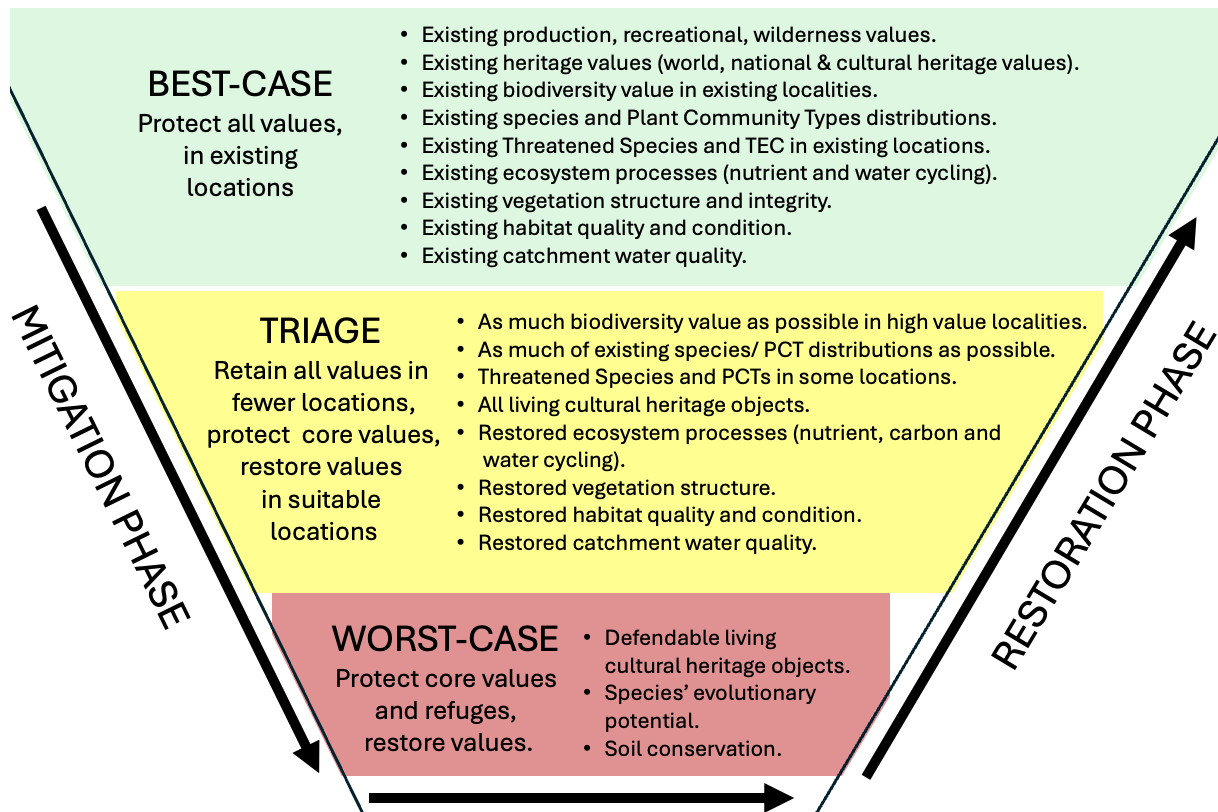


Figure 5. A generic example of how values might be prioritised (tiered) under different degradation scenarios, based on condition and inherent differences in defensibility and restorability among values (See also: [Table 2](#)).

3.3 Frameworks and Tools for Adaptation

3.3.1. State-and-Transition Modelling for Forest Adaptation

Summary

State and transition models (STMs) are powerful conceptual tools that help forest managers visualise, anticipate, and plan for ecosystem change under climate-driven disturbance. By mapping possible states and transitions, STMs support adaptive management, scenario planning, and the identification of critical intervention points^{115–120}. Their use is increasingly recommended in Australian forest adaptation guidance and is central to effective futures-thinking workshops.

What is State-and-Transition Modelling?

- **Definition:** STMs are diagrammatic frameworks (often box-and-arrow diagrams) that describe the known states (e.g., old growth, maturing forest, resprouting stands) and possible transitions (e.g., disturbance, dieback, regeneration) within an ecosystem, or between community types.
- **Purpose:** They help managers understand how vegetation structure, composition, and function may change in response to different disturbance regimes, management actions, or climate scenarios^{121–124}.
- **Application:** STMs can be used to:
 - Map baseline ecosystem dynamics.
 - Forecast potential future states under climate change.
 - Identify thresholds and tipping points.
 - Support transparent, participatory decision-making.

Why Use STMs in Forest Adaptation?

- **Visualising Complexity:** STMs make complex ecological processes and uncertainties visible, supporting shared understanding among managers, stakeholders, and communities.

- **Identifying Triggers:** By mapping transitions, STMs help define decision triggers—thresholds at which management strategies should pivot (e.g., from resistance to acceptance or direct intervention).
- **Scenario Planning:** STMs are essential in futures-thinking workshops, enabling participants to explore best-case, triage, and worst-case scenarios, and to plan for both desirable and undesirable futures.
- **Supporting Adaptive Management:** STMs provide a framework for iterative learning, monitoring, and adjustment of management actions as new information emerges.

Developing and Using STMs: Practical Guidance

1. **Map Current States and Known Transitions**
 - Identify the main vegetation states in your forest (e.g., old growth, maturing, resprouting, degraded).
 - Document known, historic transitions (e.g., fire, drought, pest outbreaks, restoration).
 - Use expert input, monitoring data, and local knowledge.
2. **Incorporate Climate Transitions**
 - Add transitions driven by climate change (e.g., increased frequency of dieback, state changes to novel communities).
 - Highlight irreversible transitions (e.g., loss of mature forms, ecosystem transformation).
3. **Identify Management Trigger Points**
 - Use the STM to define thresholds for action (e.g., loss of reproductive maturity, failure of natural regeneration, repeated disturbance).

- Link these triggers to pre-agreed management responses (e.g., deploy restoration teams, shift to alternative species).
4. **Integrate with Adaptive Management and RAD Frameworks**
- Use STMs alongside the Resist–Accept–Direct (RAD) framework to clarify when to resist change, accept transformation, or direct ecosystems towards new states.
 - Ensure that monitoring and feedback loops are built into the STM process.
5. **Facilitate Stakeholder Engagement**
- Use STMs in workshops to build con-

sensus, clarify values, and explore trade-offs.

- Encourage transparent documentation of assumptions, uncertainties, and decision pathways.

Examples:

CSIRO and DCCEEW (Cth) have developed archetypal STMs that reflect baseline states and transitions for eucalypt forests, woodlands, and mallee shrublands, providing templates for local adaptation:

- [Eucalypt Forests STM](#)¹²⁵.
- [Eucalypt Woodlands STM](#)¹²⁶.
- [Mallee woodlands and shrublands STM](#)¹²⁶.

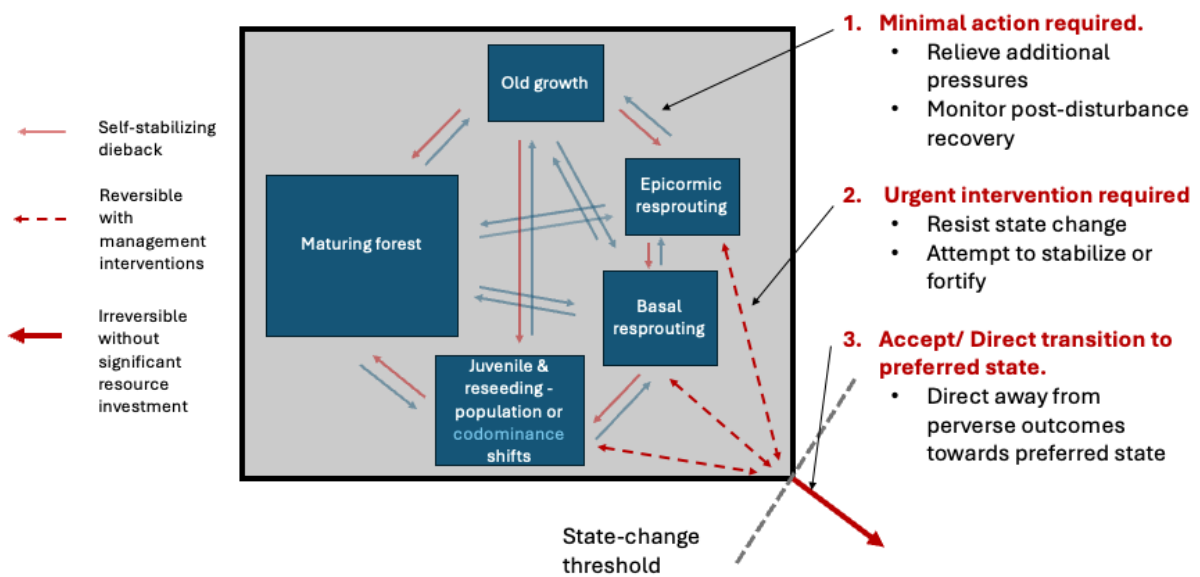


Figure 6. Illustrative state-and-transition model showing reversible and irreversible dynamics in a dieback-affected system. Departure from the central “black box” represents a state change that is unlikely to be reversed without significant resource investment or within meaningful time frames. Following a dieback event, early indicators of lost self-recovery capacity, such as the absence of reproductively mature individuals, seed bank depletion, or interruption of key life history stages, should be closely monitored to inform timely management intervention.

Actionable Recommendations for Managers

- Develop or adapt an STM for your management context using available templates and local data.
- Use STMs to inform management planning, monitoring, and review cycles.
- Incorporate STMs into futures-thinking workshops to support scenario planning and stakeholder engagement.
- Regularly update STMs as new information, monitoring data, and climate projections become available.
- Document decision triggers and management responses within the STM to enable timely, transparent action.

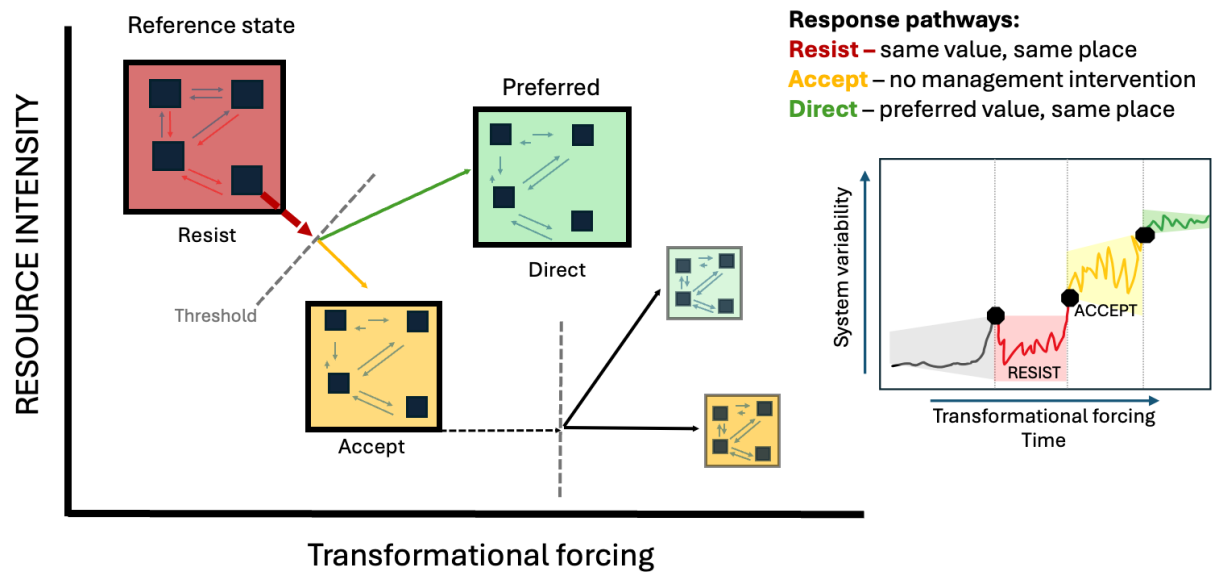


Figure 7. State-and-transition models enable the mapping of multiple possible futures for forest systems under management. In futures-thinking workshops, these models help develop a shared conceptual understanding of potential ecosystem trajectories, incorporating both empirically supported predictions and informed assumptions. While the accuracy of any scenario can only be assessed retrospectively, state-and-transition models facilitate consideration of which transitions may be influenced by timely management interventions, and which may be inevitable under persistent climate forcing. (See also: Resist–Accept–Direct Framework [Section 3.8](#)). Inset figure adapted from Lynch et al. (2022)¹²⁷ and Cravens et al. (2024)¹²⁸.

3.3.2. Key Threatening Processes

Key Threatening Processes (KTPs) are formally listed ecological threats that trigger conservation action under Commonwealth and State legislation. They offer a strategic entry point for adaptive forest management, particularly in contexts of dieback and climate succession. This section outlines how KTPs can be used to justify interventions, prioritise resources, and coordinate across agencies without requiring legislative reform.

Key Points for Managers

- KTPs are legally recognised threats. They provide a science-based rationale for action and are embedded in legislation such as the EPBC Act 1999 (Cth) and Biodiversity Conservation Act (2016).
- KTPs support adaptive planning. They can be used to reorient management plans toward emerging risks without waiting for policy reform.
- KTPs enable cross-agency coordination. They offer a shared framework for collaboration across jurisdictions and programs.

Strategic Use of KTPs in Forest

Management Planning

Forest managers can use KTPs to:

- Embed threat recognition in management plans to justify interventions and prioritise resources.
- Trigger adaptive planning processes using KTP listings as a legal and scientific basis for action.
- Support revision of forest values use planning to reassess protected forest values where climate change impacts are likely to undermine original conservation intent.
- Enable cross-agency coordination using KTPs as a common framework for collaboration.

Practical Guidance

- Reference KTPs when proposing amendments to management plans.
- Use KTPs to align local actions with state and national conservation priorities.
- Advocate for interpretive flexibility and pilot exemptions where legacy frameworks constrain adaptive responses.

Table 4: Key Threatening Processes (KTPs) Relevant to Dieback and Climate Change

Threatening Processes	Jurisdiction	Management status
Dieback caused by <i>Phytophthora cinnamomi</i>	Cth, NSW	TAP exists (EPBC Act 1999 (Cth)); hygiene guidelines and local strategies (NSW)
Fire regimes causing biodiversity decline	Cth, NSW	Listed; fire management strategies under Saving our Species (SoS) Program (NSW)
Loss of climatic habitat due to greenhouse gases	Cth	Listed; no TAP due to global causal origins, local adaptation plans encouraged
Novel biota (e.g. Myrtle Rust)	Cth, NSW	Listed; managed via national action plans and SoS strategies
Bell Miner-associated Dieback	Cth, NSW	Listed; guidance needed for context-specific management

3.3.3. Using Climate Adaptation Strategy Documents

Summary

National and state climate adaptation strategies provide a policy foundation for updating forest management plans in response to dieback and climate succession.

While these strategies often lack operational detail, they offer a legal and scientific rationale for enabling adaptive forest management interventions. Forest managers can use these frameworks to advocate for interpretive flexibility, pilot exemptions, and targeted amendments to legacy plans.

Key Points for Managers

- National and state adaptation strategies acknowledge the scale of climate threats, but often lack practical guidance for forest managers.
- These strategies can be used to justify changes in management planning that enable localised interventions, especially where current plans constrain adaptive responses.
- Forest managers play a critical role in translating high-level policy into actionable tools and treatments.

Climate Risk Assessments and Adaptation Plans

Australia's National Climate Risk Assessment (2025) and National Adaptation Plan (2025) rate the risks of ecosystem transformation or collapse, and loss of nature's benefits to people as very high. They note that many of our landscapes will likely be significantly degraded by climate change. They project that the risk will increase to very high-severe by 2050 and remain severe to 2090. They project major changes to ecosystem composition, substantial changes to species distribution and abundance, and ongoing interactions with other threats.

The NSW Government have developed a [Climate Change Adaptation Strategy \(2024\)](#) and [NSW Action Plan 2025-2029](#) legislatively supported by the Climate Change (Net Zero Future) Act 2023.

Both national and state-level plans highlight the urgency of enabling adaptive forest management. However, they provide limited operational guidance for managing landscape-scale impacts such as dieback and climate succession. They encourage the use of risk assessment tools that support scenario planning, adaptive pathways, and contingency responses as detailed in this document.

Practical Guidance

Reviewing and Updating Management Plans:

- Check if your management plan explicitly addresses the risks of dieback and climate succession.
- Check whether there is a clear process in place to regularly review and update management plans in response to new national and state climate risk assessments and adaptation strategies.
- Identify any gaps where current plans do not address nationally significant risks or recent scientific guidance.
- Use these gaps as an opportunity to advocate for locally tailored strategies that align with national and state goals but are grounded in site-specific ecological conditions and realities.
- Refer to risk assessment and adaptation planning frameworks to demonstrate where current plans fall short, and to justify amendments that enable proactive, adaptive interventions.

3.3.4. Climate Adaptation Frameworks

Summary

A range of climate-adaptive planning frameworks are available to help managers respond to novel and global climate risks. These frameworks share common elements: risk assessment, scenario planning, and iterative, participatory review cycles.

Examples:

- AdaptLog (CSIRO)¹¹³
- Values, Rules and Knowledge⁹⁴
- Renovating Nature typology⁹⁷
- Resist–Accept–Direct (RAD) framework^{91–93,127,129,130}
- Risk-based adaptation pathways^{100,101}

These frameworks vary in complexity and terminology. Their practical value will become clearer through field application by forest managers. In selecting a framework to support their

adaptation planning, forest managers should aim to balance operational simplicity with ecological nuance. It is important to recognise that no single tool will fit all contexts, and mitigation of hazardous impacts to values may not always be achievable. A detailed explanation of applying the Resist–Accept–Direct (RAD) framework is provided in [Subsection 3.8](#) and [Appendix D](#).

Practical Guidance

- Identify whether your organisation has adopted an adaption planning framework and process.
- Assess the extent to which the framework and process enable the timely response to dieback and climate succession risk.
- Research and compare adaptation planning frameworks and identify those that are most relevant to your management context.

3.3.5. Resist–Accept–Direct (RAD) Framework

The **Resist–Accept–Direct (RAD)** climate-adaptive management framework is an emerging climate-adaptive planning approach^{92,127,130}, initially developed in the United States and now increasingly explored within Australian contexts^{81,131–134}. The RAD framework also appears explicitly in the National Adaptation Plan (2025)¹. The RAD framework assists managers to anticipate, plan for, and respond to ecosystem change by categorising management objectives into three strategic pathways:

- **Resist:** Strategies that seek to maintain current ecosystem states by halting or removing threats and conserving existing biodiversity. While this approach underpins much of the traditional conservation paradigm, its feasibility, risk profile, and return on investment at landscape scale are increasingly uncertain under compounding climate pressures.
- **Accept:** Strategies that allow for ecosystem transformation and natural adaptation, recognising that some change is inevitable. This pathway carries inherent uncertainty,

as ecosystem structure and function may be degraded by repeated disturbance, and recovery could take centuries.

- **Direct:** Strategies that actively guide ecosystem composition or function towards states considered suitable for anticipated future climates.

Selecting the most appropriate strategy for a given landscape requires broad-based agreement on desired conservation values and ecosystem services, both now and into the future.

While the RAD framework provides conceptual clarity and transparency, its limitations should also be acknowledged. Many RAD pathways are not entirely novel and are already reflected, at least informally, in Australian natural resource management—particularly in highly modified or degraded landscapes. Furthermore, despite the RAD framework’s recognition that resisting change may be ineffective or unfeasible in some contexts, legislative, policy, and management guidelines in Australia continue to emphasise Resist-type obligations, especially for iconic species and communities.

Case Studies: Contrasting Approaches in Ash Forests

Two contrasting strategies are evident in the management of ash forest communities in different jurisdictions:

1. **Resisting Transition in Victorian Temperate Rainforests:** Following the 2019–20 bushfires, which impacted 88,000 ha of ash forest and killed 25,000 ha of young ash trees, the Victorian Government funded a \$7.7 million operation involving manual harvesting and reseedling. Despite the high likelihood of climate maladaptation, this intervention was driven by the
2. **Accepting and Resisting in Alpine Ash Forests, Kosciuszko National Park:** In remote areas of Kosciuszko National Park, a mixed management response was adopted: (1) accepting the transition of impacted forests to novel communities, and (2) directing resources towards defending and retaining remaining unburnt

¹National Adaptation Plan (2025), Department of Climate Change, Energy, the Environment and Water, Canberra. CC BY 4.0. p 38

stands. This approach acknowledged the high risk of climate maladaptation, persistent fire threat, and limited resources, balanced against public expectations for resistance.

In one example, government intervention is highly resource-intensive, aiming to maintain a climate-sensitive yet iconic value. In the other, managers are compelled to take a pragmatic approach, as resourcing constraints limit the scale

at which resistance is possible, despite legislative emphasis.

Both cases underscore the need for proactive planning and scenario-based triage, enabling preparations for worst-case outcomes. As climate change presents a continent-wide threat to all species and communities, accepting change is likely to become the default action in many contexts, driven by resource limitations and legislative barriers.

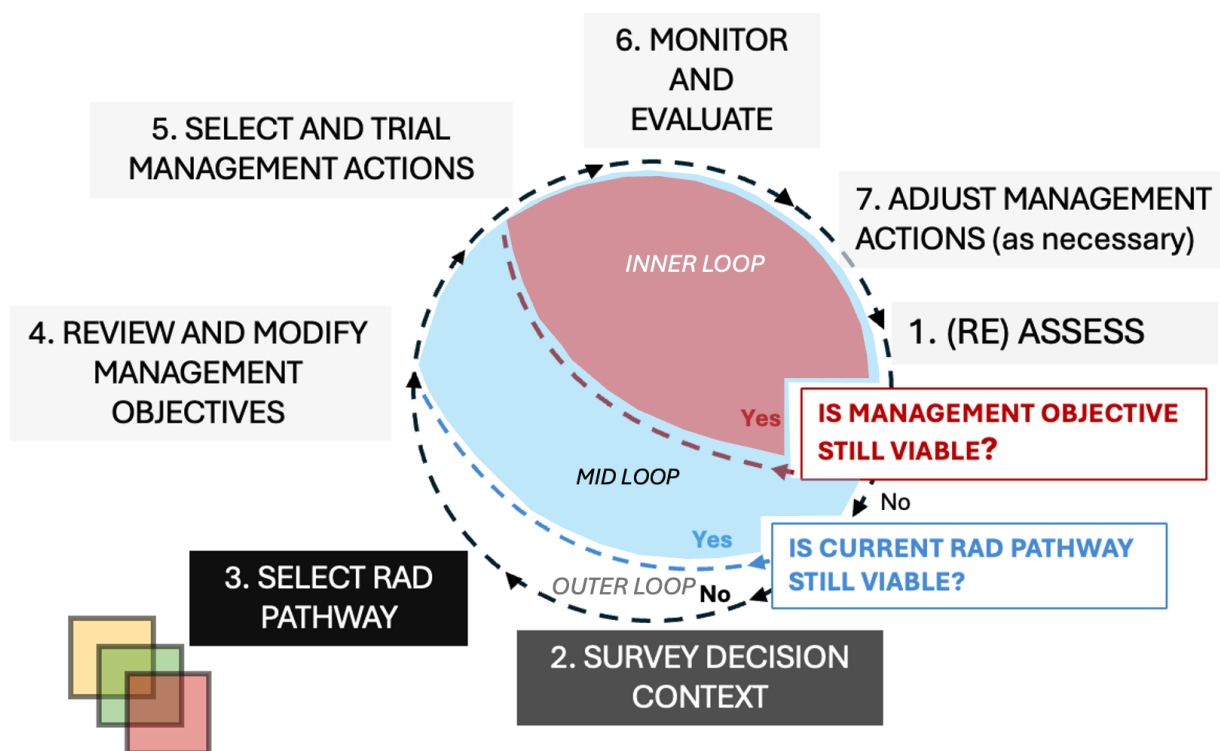


Figure 8. Adaptive Management Decision Loop with Climate-Responsive Resist-Accept-Direct Pathways. Figure adapted from Lynch et al. (2022)¹²⁷.

Using Decision Loops

Figure 8 presents the traditional six-step adaptive management decision loop, enhanced with three nested pathways that reflect varying degrees of ecological change and management response.

- **Inner Loop – Staying the Course:** Represents management directed towards maintaining existing or historic ecological conditions, where ecological values remain largely intact and viable. While the objective is to preserve current system states, management actions may still require iterative adjustment in response to emerging climate-driven instability.
- **Middle Loop – Adapting the Course:** Reflects a shift in management objectives due to observable climate-induced changes in ecological character. The goal is to stabilise the system while retaining as much of its structure, function, and values as possible. This pathway acknowledges transformation but seeks to moderate its trajectory.
- **Outer Loop – Reimagining the Course:** Applies in contexts where climate-driven disturbances have caused irreversible transformation or degradation. Management under this pathway incorporates consideration of Accept and Direct strategies, recognising that some systems may no longer be recoverable to their previous states and may require redefinition of conservation goals.

This conceptual model supports managers in identifying when to pivot between priority values and strategies, particularly in landscapes where ecological thresholds have been crossed or are at risk.

Appendix D provides examples of Resist-Accept-Direct management pathways mapped to forest values

Australian examples:

- Murray–Darling Basin¹³¹
- Parks Victoria Conservation Action Plans^{132,133}
- Subalpine snow-gum dieback¹³⁴
- Alpine Ash forest management⁸¹
- Great Barrier Reef¹³⁵

3.4 Science-Informed Planning Approaches

3.4.1. Ecological Niche and Functional Trait-Based Planning

Summary

As climate change accelerates, forest managers face unprecedented uncertainty about which species and communities will persist, thrive, or decline. Traditional approaches that rely on historical species assemblages or local provenance are increasingly inadequate. Instead, integrating ecological niche modelling and functional trait-based planning provides a scientific foundation for selecting species, provenances, and interventions that maximise resilience and adaptive capacity in a rapidly changing environment.

1. Ecological Niche Modelling

Ecological niche models use species occurrence data and climate variables to predict where species are likely to persist under current and future climate scenarios^{136,137}. These models help managers:

- Identify climate refugia: Areas likely to remain suitable for target species or communities as climates shift.
- Guide translocation and restoration: Select sites for assisted migration or restoration that match the future climatic requirements of key species.
- Prioritise interventions: Focus resources on areas with the highest likelihood of long-term success.

Practical tools:

- **Restore and Renew**: A web tool that generates species lists and maps suitable provenances (from within local genetic populations) for restoration.
- **Climate Refugia NSW**: A web tool that identifies and visualises presumed refugia for threatened species in NSW.

Limitations:

- Niche models indicate climatic suitability, not actual establishment or persistence, which may be limited by dispersal, disturbance, or biotic interactions.
- Most models operate at the species level and may not capture local adaptation or genetic diversity within species.

2. Functional Trait-Based Planning

Functional traits are measurable characteristics of plants that influence their survival, growth, and reproduction under different environmental conditions. Trait-based planning enables managers to:

- Assess resilience and vulnerability: Identify which species or populations are likely to withstand key stressors (drought, fire, pests).
- Diversify plantings: Combine species and provenances with complementary traits to buffer against a range of future risks.
- Inform restoration and adaptation: Select seed sources and species mixes that maximise adaptive capacity and ecosystem function.

Key traits to consider:

- Fire response: Epicormic/basal resprouting, obligate seeding, bark thickness^{2,10,79,138}.
- Climatic traits: drought, flood, frost and heat tolerance^{8,36,63,139–142}.
- Pest and disease resistance: Known resistance to local threats (e.g., *Phytophthora*, Myrtle Rust)^{11,12,143,144}.
- Reproductive traits: Time to maturity, seed dispersal mechanisms, seed bank longevity.^{23,77,145,145}

Trait data sources:

- Published trait databases (e.g., [TRY](#), [Aus-Traits](#)).
- Local field surveys and monitoring.
- Field trials to validate selections.
- Collaboration with research institutions.

Integrating Niche and Trait Approaches in Management

Best practice is to combine ecological niche modelling and trait-based planning with local knowledge and adaptive management:

- **Restoration:** Use niche models to select suitable sites and trait data to choose resilient species/provenances.
- **Translocation:** Prioritise recipient sites that match both the climatic niche and trait requirements of the species.
- **Portfolio approach:** Diversify plantings across sites, species, and traits to spread risk and increase the likelihood of success.
- **Monitoring and feedback:** Track survival, growth, and ecosystem function to refine models and trait selection over time.

Example: The Greening Australia and Upper Snowy Landcare Network restoration project, the Monaro Comeback, in NSW combined climate-adapted provenances of *Eucalyptus viminalis* with unaffected co-occurring species, using both niche and trait data to restore resilience after severe dieback

Recommendations for Managers

- Incorporate niche and trait data into all stages of planning: From risk assessment to restoration and monitoring.
- Use available tools and resources: Leverage web-based tools, trait databases, and local expertise.
- Collaborate across disciplines: Work with ecologists, geneticists, and local stakeholders to ensure robust, context-specific decisions.
- Embrace adaptive management: Treat interventions as experiments, monitor outcomes, and adjust strategies as new information emerges.

3.4.2. Genomically-informed Planning

Summary:

Climate-induced dieback and ecological succession are exposing the limitations of traditional forest management approaches. Genomic-informed management offers a powerful set of tools to enhance the resilience and adaptive capacity of forest ecosystems^{146–148}.

By leveraging advances in genomics, managers can make evidence-based decisions about seed sourcing, restoration, and conservation that account for both current and future climate risks.

Why Genomic Variation Matters for Forest Adaptation

- Genetic diversity underpins resilience: Forests with high genetic diversity are better able to withstand and recover from climate extremes, pests, and diseases.
- Local variation may not be enough: As climates shift, local provenances may become maladapted. Genomic tools help identify and source genotypes with traits suited to future conditions.
- Landscape genomics enables targeted action: By mapping adaptive and neutral genetic variation across populations, managers can design restoration and conservation strategies that maximise evolutionary potential.

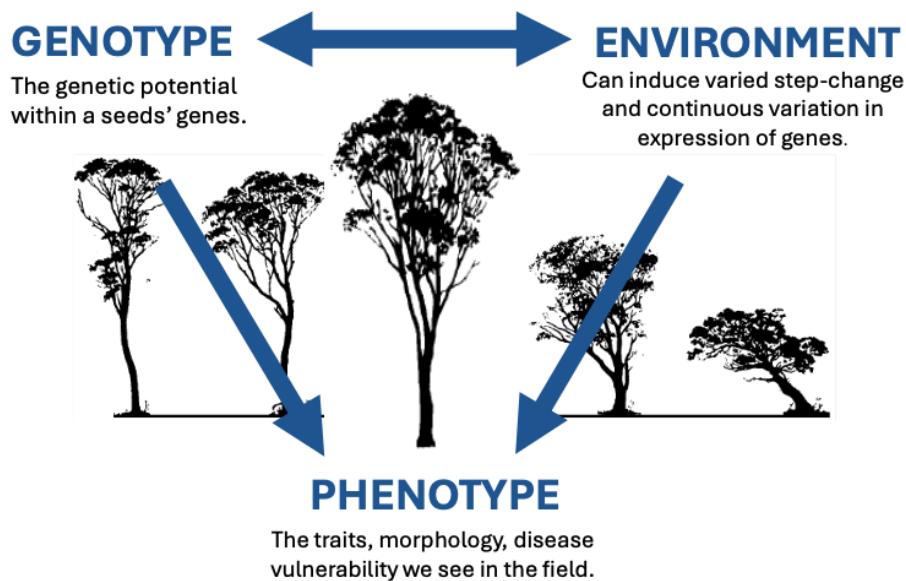


Figure 9. Understanding and leveraging the variation within the species we are managing. A trees' phenotype (the traits and characteristics we observe in the field) arises from interactions between its genotype and the environment. Acclimation potential refers to the extent of adaptive change possible within mature individuals, plasticity refers to the extent of adaptive change possible when seeds sharing a common genotype are grown in different environments. Understanding the genetic and environmental bases of adaptive phenotypes and characterising existing variation across a population is assessing if there is any value in climate-adaptive provenancing. This requires genotyping of seed lots with different adaptive traits or climatic distributions, and assessing whether differences persist in their offspring grown under common garden conditions, such as in seed production areas, provenance trials, or restoration sites.

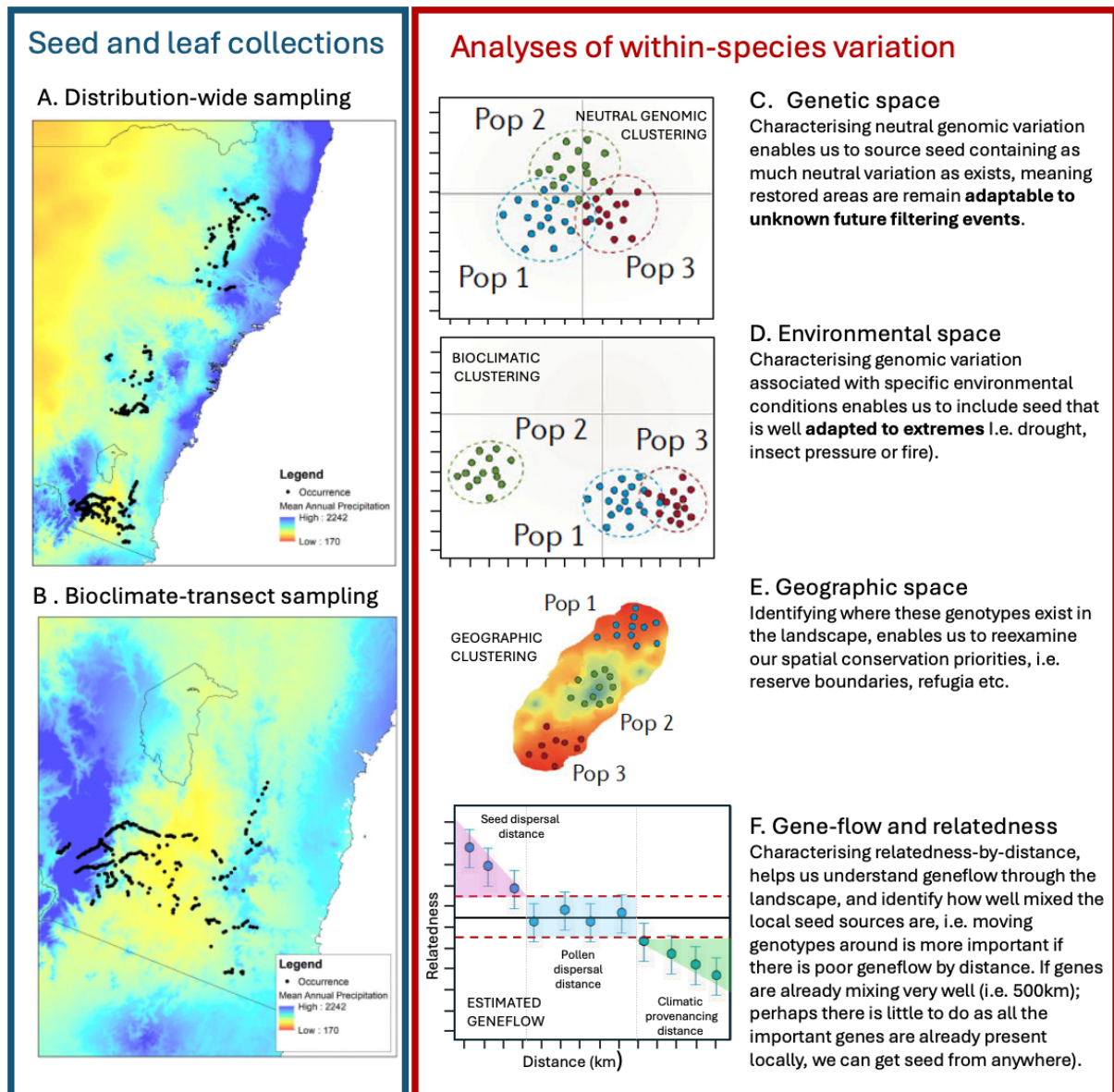


Figure 10. Landscape genomics examines both adaptive and neutral genetic variation throughout a species' range. This process begins with (a) collecting seeds and leaves from across the species' full distribution, as well as (b) taking targeted samples along key environmental gradients. These collections allow scientists to (c) analyse neutral genetic diversity within populations, (d) identify how adaptive genetic groups are clustered in different bioclimatic zones, and (e) map the geographic spread and estimate gene flow in relation to distance. By providing this detailed understanding, landscape genomics supports informed seed sourcing strategies, helping to determine the true extent of what is considered 'local' for restoration and conservation purposes. Figures a-b courtesy of Margaret Mackinnon and Justin Borevitz; figures c-f adapted from Breed et al. (2019)¹⁴⁷.

Key Concepts and Tools

1. Climate-Adjusted Provenancing

- **Definition:** Sourcing and planting seed from populations adapted to projected future climates, not just local conditions.
- **Application:** Use tools like the [Restore and Renew](#) to select seed sources based on climate projections and genetic diversity.
- **Benefit:** Increases the likelihood that restored populations will thrive under future climate scenarios.

2. Genomic predictions for provenance suitability

- **Definition:** The exploration of genetic variation correlated with bioclimatic variables across landscapes to identify adaptive traits and inform management.
- **Application:** Whole-genome sequencing and trait surveys can reveal which populations or genotypes are correlated with greater resilience to drought, heat, or disease, enabling prediction of maladaptation or suitable to future climate scenarios.
- **Benefit:** Enables informed decisions about the assisted gene flow, translocation, and ex-situ conservation.

3. Genomically-Informed Restoration

- **Definition:** Using genetic and genomic

data to guide species and provenance selection for restoration projects.

- **Application:** Combine local, climate-adjusted, and genomically-predicted seed lots to spread risk by capturing neutral and adaptive genetic diversity.
- **Benefit:** Reduces the risk of restoration failure and ecosystem collapse.

4. Assisted Migration and Species Translocation

- **Definition:** Moving species or populations to areas projected to become suitable under future climates.
- **Guidelines:** Follow national and state policies (e.g., [Translocation Operational Policy \(NSW\)](#)) and conduct risk assessments to avoid unintended consequences.

5. Ex-Situ Conservation

- **Definition:** Conserving a species or community in another location with reduced exposure to hazards.
- **Application:** Prioritise ex-situ conservation for species at high risk of local extinction or with limited dispersal capacity.
- **Benefit:** Safeguards irrecoverable genetic resources (existing diversity and adaptive potential) in seed banks, seed production areas, and living collections.

- Benefit

Practical Steps for Managers

1. Assess Genetic Diversity and Adaptive Potential

- Use landscape genomics to map genetic variation within and among populations^{149,151}.
- Identify populations or seed lines with traits conferring resilience to key stressors (drought, heat, pests)^{144,152–154}.

2. Design Restoration with Genomic Data

- Select seed sources using CAP and admixture provenancing^{146,154–157}.
- Monitor survival, growth, and ecosystem function in restored sites; adapt strategies as new data emerge.

3. Integrate Genomics into Risk Assessment

- Include neutral genetic diversity and adaptive potential in value-based risk assessments¹⁵⁷.
- Use genomic data to inform decisions about in situ vs ex-situ conservation, and to prioritise interventions.

4. Collaborate and Share Data

- Partner with research institutions for experimental design, data analysis, and monitoring.
- Engage with networks like the Dieback and Climate Succession Network (DCSN) to share lessons and resources.

5. Follow Best-Practice Guidelines

- Use national and international standards for seed sourcing, translocation, and restoration (e.g., [Florabank](#), National and state guidelines^{158–160}).

Risks and Limitations

- Uncertainty about future climates and adaptation: Genomic predictions require

field validation (i.e., planting side-by-side with historical community and assessed for improved long-term performance; ongoing monitoring and adaptive management are essential).

- Potential outbreeding depression risk can be addressed by understanding genetic variation balanced against risk assessment, and field trials are needed before large-scale implementation^{159,160}.
- Regulatory and social barriers: Moving species or genetic material outside historical ranges may face policy and community resistance.

Case Studies and Resources

- The [Monaro Comeback](#) combined climate-adapted provenances and unaffected co-occurring species to during restoration of dieback-affected *Eucalyptus viminalis* woodlands.
- [Restore and Renew](#) provides a web tool to support climate-adjusted restoration in NSW.
- [Climate-ready revegetation](#) guide for natural resource managers by AdaptNSW.
- The National Seed Bank and regional seed production areas (SPAs) safeguard genetic diversity for priority species.

Recommendations

- **Embed genomics in all stages of adaptation planning:** From risk assessment to restoration and monitoring.
- **Diversify restoration strategies:** Use a portfolio approach to spread risk and maximise resilience.
- **Invest in capacity building:** Train staff and partners in genomic literacy and best practices.
- **Advocate for policy support:** Ensure regulatory frameworks enable the use of genomics in adaptation.

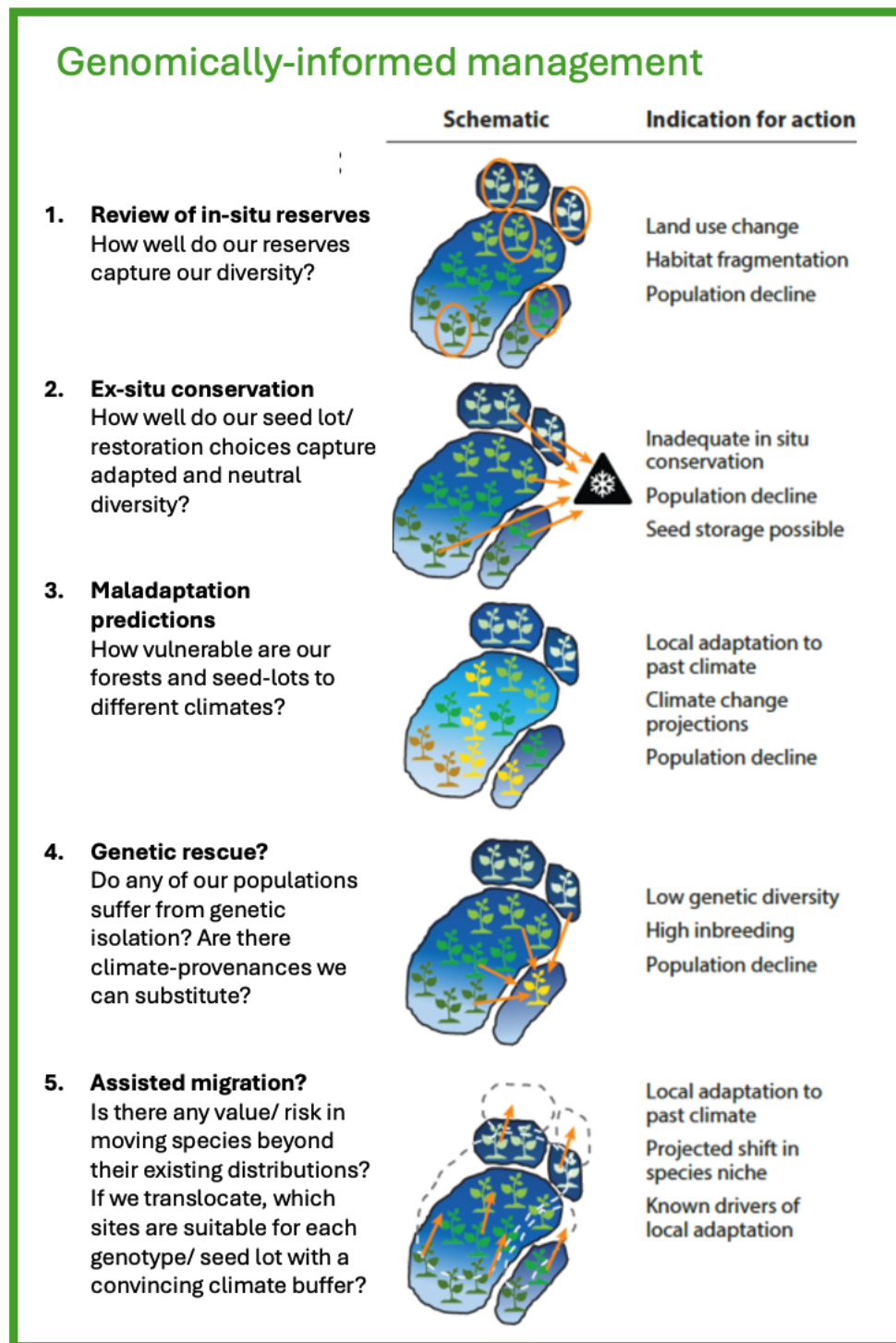


Figure 11. Climate change poses complex challenges for forest management and raises critical questions about effective interventions, and the variation in the forests under management. When these details are resolved, manager's can better understand the risks and value associated with management actions being considered. Landscape genomic mapping and targeted analyses for priority species provide valuable insights by systematically mapping and characterising the spatial distribution of neutral and adaptive genomic diversity^{149,150}. This mapping process improves understanding of genetic variation within species and helps managers conserve essential genetic resources, supporting informed management and adaptive strategies^{147,148}. Figure adapted from Aitken et al. (2024)¹⁴⁸.

3.5 Decision-Making and Implementation

3.5.1. Decision-Making Triggers and Condition Thresholds

Summary

Decision triggers are essential tools in adaptive management, helping practitioners recognise when to shift strategies in response to ecological change. While formal thresholds are ideal, uncertainty and limited data often necessitate informal or scenario-based approaches. Proactive planning ensures more effective responses to climate-driven change, especially when time and resources are constrained and values are at risk.

Decision triggers

Decision triggers are thresholds used in adaptive management to signal when a strategy must change, whether due to major events, deteriorating conditions or approaching tipping points^{161–168}. While formal thresholds supported by monitoring are ideal, ecological uncertainty and limited data often lead to more informal decision-making.

Trigger points can be adapted for use in data-poor contexts and under competing objectives¹⁶⁹. Scenario mapping and stakeholder engagement help build social licence and clarify when to pivot. The Resist–Accept–Direct (RAD) framework offers a pragmatic structure for expressing thresholds (See: [Appendix D](#)).

Incorporating trigger points into management plans will enable the timely implementation of pre-agreed management interventions. This may require introducing clauses into the management plan.

Example:

“In this place, at this time, our response to changing ecological conditions [insert change] is to [resist/ accept/direct] this change by [insert control] to preserve [insert value]. If [insert threshold] is crossed, we will pivot to [resist / accept / direct] to preserve [insert value]”⁹¹.

Importantly, not all dieback events warrant intervention; Australian forest systems have inherent resilience. However, advance planning is essential to identify which thresholds indicate a state change that require a response. *Examples:*

- Large-scale dieback may trigger deployment of Damage Assessment and Restoration Teams.
- Demographic skew within a stand may prompt restoration using species suited to novel disturbance regimes.
- Exceeding fire frequency thresholds may shift restoration
- Post-disturbance erosion risk may trigger rapid reseedling or terraforming to stabilise soil and water flow.

Stakeholder participation is critical when setting thresholds for threatened values¹⁶⁷. In the absence of planning, decisions often occur haphazardly. Planning for worst-case scenarios enables faster, more strategic responses and better use of limited resources.

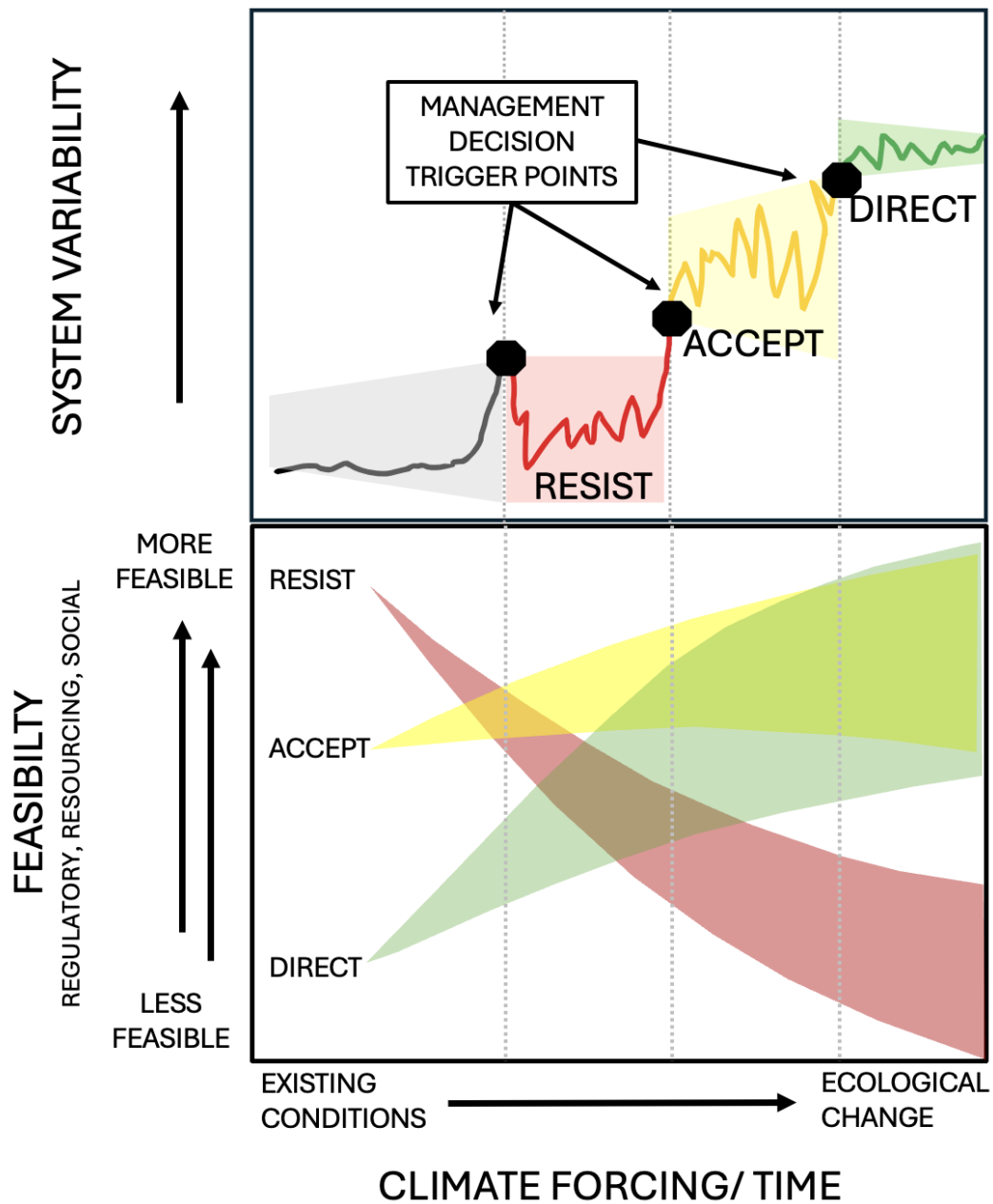


Figure 12. Management decision trigger-points in response to ecosystem variability and declines in condition. **Top:** Crossing of condition thresholds may trigger management decision points. **Bottom:** The regulatory, resourcing feasibility and social licence for some types of interventions change in response to system condition and risks associated with the scale of impact. Figure adapted^{127,128}.

3.5.2. Hierarchy of Risk Control Effectiveness

Summary

This section introduces a hierarchy of risk controls and treatments, adapted from workplace and bushfire risk management frameworks. These six interventions are categorised by their mode of action and long-term effectiveness. Selecting interventions requires consideration of value sensitivities, competing risks, and the specific management context.

1. Elimination Controls

- Aim to remove the hazard entirely by addressing root causes.
- In forest contexts, this can refer to carbon emission reduction, which is beyond the scope of local forest managers but critical at national and international levels.
- Elimination controls also include the eradication of dieback inducing insects and pathogens, which is rarely feasible once they are established.

2. Substitution Controls

- Replace vulnerable system components with more resilient alternatives.
- *Examples:* climate-adjusted species mixes during restoration, or genomic selection for drought-tolerant provenances.

3. Isolation Controls

- Separate vulnerable values from hazards.
- *Examples:* in situ vs ex-situ conservation decisions, such as relocating species to more suitable habitats or protecting remnant populations in controlled environments.

4. Engineering Controls

- Modify the environment to reduce risk.
- *Examples:* terraforming, hydrological adjustments, and firebreaks to buffer against disturbance.

5. Administrative Controls

- Change how forest systems are managed.
- *Examples:* policy changes to forest management, securing the conservation of land for climate refuges. Changing rules to enable adaptive management and substitution controls.

6. Asset Protection Controls (APCs)

- Direct protection of high-value assets.
- *Examples:* fencing, manual watering, or targeted pest control, typically reserved for small, high value and defensible areas.

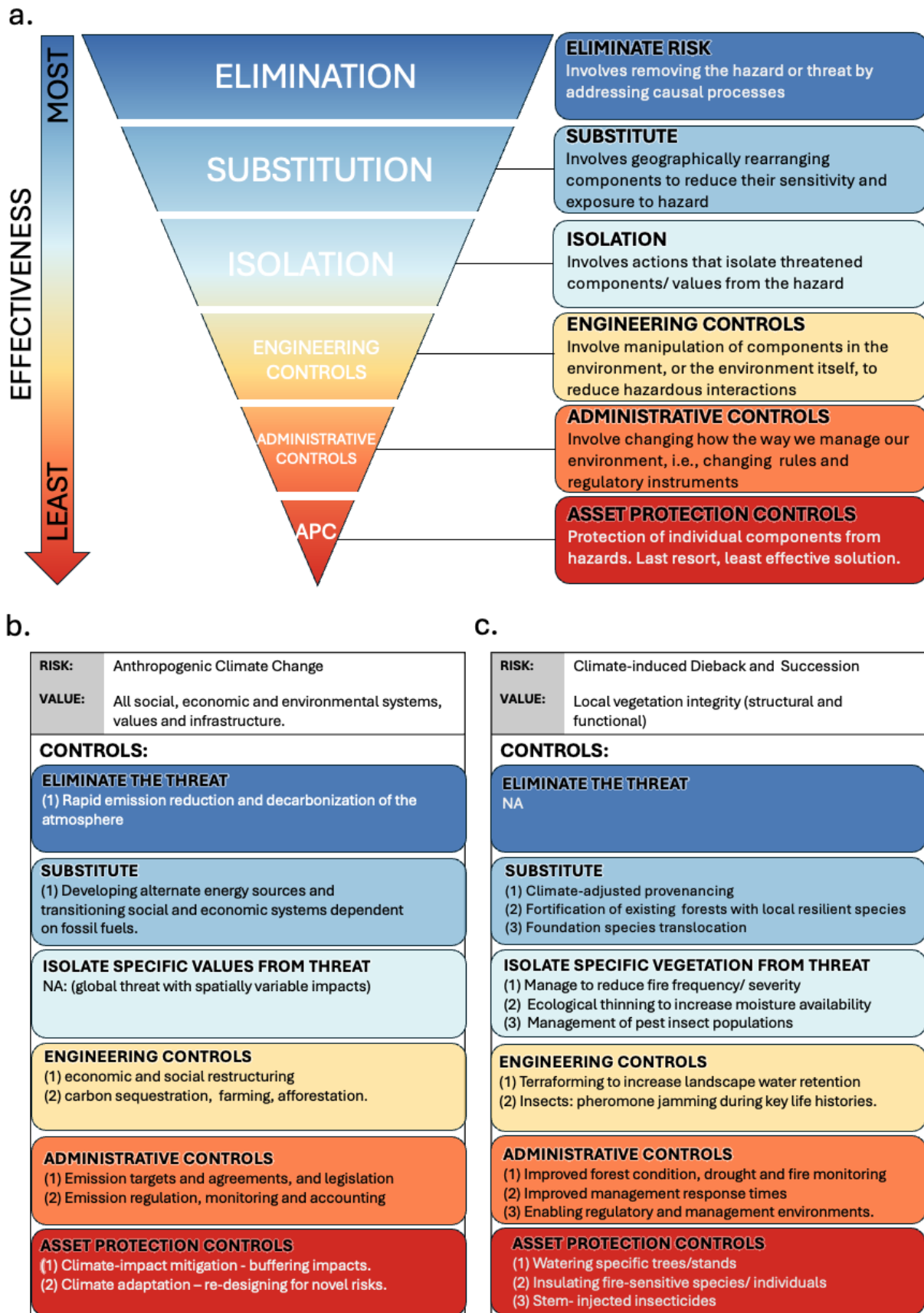


Figure 13. (a) A generalised control hierarchy for climate succession and dieback based on the mode of risk reduction and examples of use (b, c). Where available and economical, managers should prioritise interventions with the most effective mode of risk reduction.

3.5.3. Inventory of Risk Controls and Treatments

Summary

This section outlines a structured inventory of risk controls and interventions relevant to mitigating threats to environmental values. These controls are categorised into six types, forming a hierarchy of effectiveness commonly used in risk management frameworks, illustrated in Figure 13).

Hierarchy of Risk Controls

- **Elimination controls** – Remove hazards by addressing root causes.
- **Substitution controls** – Reconfigure system components to reduce climate sensitivity.
- **Isolation controls** – Separate vulnerable values from hazards.
- **Engineering controls** – Modify environmental components or conditions to reduce risk.
- **Administrative controls** – Adjust planning and management processes to limit exposure.
- **Asset protection controls** – Directly shield specific elements or sites from harm.

While the options to reduce risks to intact in

situ forest values are limited, the restoration of degraded areas offers a strategic opportunity to reduce future risks. Forward-looking restoration planning can help prevent high magnitude declines and prolonged disruption of ecosystem function.

As discussed, risk tolerance varies depending on the condition of the target value. Some management controls aim to enhance resilience in existing vegetation, while others suit restoration of degraded land. A coordinated approach across conditions and tenures is ideal. Effectiveness, scale, resourcing, regulatory support, and social licence must all be considered in selecting management controls.

One novel administrative control — the **Rapid Dieback, Damage and Recovery Assessment (RDDRA)** process - is outlined in [Appendix I](#).

A full description of all control types and treatments and supporting resources is provided in:

- [Appendix E: Substitution controls](#)
- [Appendix F: Isolation controls](#)
- [Appendix G: Engineering controls](#)
- [Appendix H: Administrative controls](#)
- [Appendix J: Asset Protection controls](#)

3.5.4. Monitoring Control Effectiveness

Summary

Many interventions currently being implemented to address forest dieback and climate-driven ecological succession are new and, in many cases, untested at scale. This novelty brings both opportunity and uncertainty, making it essential to rigorously monitor, trial, and evaluate these management efforts.

The Vital Role of Local Forest Managers

At this stage, local forest managers are vital to the success of these interventions. Their on-ground knowledge, adaptability, and direct engagement with changing forest conditions position them as the primary agents for:

- **Trialling new approaches:** Managers are best placed to adapt interventions to local contexts and operational realities.
- **Evaluation:** Their observations and

records are crucial for understanding what works, what doesn't, and why.

- **Communication:** Local managers play a key role in sharing outcomes, both successes and setbacks, with peers, researchers, and policymakers.

The Need for Effective Monitoring

Given the experimental nature of many interventions, effective monitoring is not optional, it is essential. Monitoring enables forest managers to:

- Track progress against objectives and detect early signs of success or failure.
- Identify unintended consequences or emerging risks.
- Build an evidence base to inform adaptive management and future decision-making.

Monitoring should be systematic, transparent, and designed to capture both quantitative and qualitative outcomes. This may include establishing baseline conditions, set clear indicators, and using a mix of field observations, remote sensing, and stakeholder feedback.

Partnering with Research Institutions

Given the complexity and novelty of interventions for dieback and climate succession, it may be highly worthwhile to partner with a research institution. Such partnerships can:

- Bring expertise in experimental design, data analysis, and ecological monitoring.
- Provide access to advanced tools and methodologies.
- Enhance the credibility and rigour of monitoring and evaluation efforts.

- Facilitate the publication and broader dissemination of findings.

Engagement with the Dieback and Climate Succession Network (DCSN)

Early and active engagement with the Dieback and Climate Succession Network (DCSN) is strongly recommended for forest managers confronting dieback and climate succession. The DCSN provides a voluntary professional collaborative platform for:

- Sharing updates on intervention trials and monitoring results.
- Discussing challenges and lessons learned.
- Connecting with other managers, researchers, and policymakers working on similar issues.
- Accessing guidance, resources, and peer support. Participation in the DCSN can help ensure that local experiences contribute to, and benefit from, the collective knowledge and innovation emerging across the sector.

[Appendix K](#) provides instructions for joining and participating in the DCSN.

Conclusion

In summary, the effectiveness of new interventions for dieback and climate succession depends on the commitment and expertise of local forest managers, supported by robust monitoring and evaluation. Partnering with research institutions and engaging with networks like the DCSN will be key to building a strong evidence base, accelerating learning, and improving outcomes for forest ecosystems facing unprecedented change.

Glossary

accept A management strategy/ pathway where forest managers allow independent ecological processes to dictate forest structure and composition. This may include a locality previously containing a forest to transition to a new ecosystem state, i.e., scrub, grassland or novel composition community. From the Resist-Accept- Direct Adaptive management framework¹³⁰; synonymous with 'autonomous adaptation'⁸¹.

active management "Management via active steps to reduce threats to forests, prepare forests for future threats, maintain the capacity of forests to recover after disturbance, and restore forests that have been degraded"⁸¹.

adapted and adaptable seed sourcing

An approach to seed sourcing for a restoration project which involves selecting seeds sources that are adapted to specific future climates or current diseases (i.e., usually characterised by niche modelling or GWAS methods), but that *also* retain the species neutral variation, i.e. the evolutionary potential (usually characterised by mapping genetic variation and clustering across a species geographic distributions. Adapted and adaptable seed lots increase the ratios of seeds in the mixture to increase the ratios of seed lines that may be rare but highly adapted to future conditions or or a threatening process, while also maintaining the species' neutral variation.

adaptive genomic variation Genomic variation with a population known to be associated with adaptive traits such as fire resilience, drought resilience, cold tolerance, etc. See also: neutral variation.

adaptive management "A data-driven form of management via iterative method development by using controlled trials to assess and refine the effectiveness of management actions in achieving management

goals. "Using available knowledge, skills and technology an action is implemented and outcomes recorded including successes, failures and potential for improvement. These learnings form the basis of the next round of decision making and trialling in a process of continuous improvement"¹⁵⁸.

climate adaptation The process of adjusting to, and preparing for, the effects of climate change to mitigate negative outcomes for communities, ecosystems and economies.

climate succession The process by which ecosystems reorganise structurally and compositionally due to climate change-driven changes in (1) the physical environment; (2) the balance of species interactions; (3) the frequency and intensity of disturbance regimes, and (4) other compounding threatening processes.

co-dominant "A tree species with a crown at the genus level of the canopy"⁸¹.

composition "The array and relative proportion of organisms within an ecosystem"¹⁵⁸.

control owner The person/ entity responsible for implementing and maintaining the control, i.e., state environment departments and forest management agencies.

dieback An atypical, sudden or gradual decline in vegetation health, usually occurring at stand or landscape scale.

direct A management strategy/ pathway where forest managers select a different future forest composition and structure for a degraded locality, fortifying a locality/ values by restoring with species that are more resilient to the threatening process. From the Resist-Accept-Direct climate-adaptive management framework¹³⁰; synonymous 'planned adaptation'⁸¹.

dominant "A tree species with a crown extending above the general level of the canopy, larger than the average tree in the

stand, with a well-developed crown”⁸¹.

ecological community Assemblage of plant species occupying a particular area, historically, ecological communities of NSW have been typified as plant community types (see: PCTs).

ex situ controls Values and control interventions that take place off-site, i.e., protecting genetic diversity currently takes place on site; however, it is possible to safeguard species’ genetic diversity off-site in seed production areas, living plantations containing capturing and preserving adaptive and neutral variation across a species’ distribution.

fortification The management action of “increasing the relative abundance or frequency of a unaffected co-occurring species, during the restoration of a dieback-affected forest system in order to stabilise ecosystem function and improve long-term resilience to future climate pressures..

frost kill Death of plant tissue or a whole seedling caused by low temperatures, or due to limited acclimation time to low temperatures..

gene flow The “transmissions of seed or pollen between individual organisms that maintain the genetic diversity of a species’ population. In nature, gene flow can be limited by dispersal distances of vectors and by topographic barriers such as mountains and rivers. In fragmented habitats, it can be limited by the separation of remnants caused by clearing”¹⁵⁸.

genetics The use of genetic (DNA) material in exploring variation across a population and relatedness among species. Because the entire genomes are very long (In *Eucalyptus* 500 million base pairs over 11 chromosomes), sequencing them and reassembling them in entirety has historically not been possible; therefore, DNA sequences have been subsampled (often less than 1% of the whole genome) to infer conclusions

about relatedness of disconnected populations. These days this is the most economical, however, as this approach by design has much lower coverage, it’s applications and resolution are limited, and it is not very effective for exploring within *Eucalyptus* populations and closely related species that often have very small amounts of variation within population, or have diverged due to rearrangements of sections of chromosomes.

genome-wide association study (GWAS)

The use of whole-genome sequencing across a population paired with trait data (i.e., variation in disease resistance, or heat tolerance, or epicormic resprouting capacity) to explore the genetic basis of trait variation observed in the field. This is a powerful method because it identifies genomic areas correlated with specific tolerances (i.e. myrtle rust resistance, or subalpine temperatures), without any prior information about the function of the correlated genes involved. Later, these genomic regions can be explored for genes with known functions.

genomics Distinct from *genetic* methods, which use a subset of DNA, genomic methods use the entire genomes (a continuous reading of all chromosomes in a tree’s DNA) in mapping of population structure, exploring genotypes that are adapted to a specific bioclimatic range or a genotype that is more or less resilient.

habitat trees “A tree identified and protected to provide habitat or future habitat for wildlife”⁸¹.

in situ values/ controls Location-specific responses, site-specific responses, i.e., existing community in existing location.

landscape genomics The use of whole-genome sequencing paired with bioclimatic data (i.e., local precipitation or temp regions), this is a variation on a genome-wide association study (GWAS), known as a landscape GWAS. Landscape genomic studies explore genetic variation within a population across it’s entire geographic and/or

bioclimatic distribution (i.e. warmest to coldest sites, or driest to wettest sites). This method is powerful for identifying seed lots that are more likely to be adapted to future climates, because it identifies genomic areas correlated with specific bioclimatic distributions (i.e., bioclimatic variables like minimum temperature, summer rainfall, soil type, etc.). While provenance trials can take decades to reveal differences in resilience among provenances, the value of landscape genomics lies in providing information important to management decisions at the timescale of months to years. There is still a need to validate GWAS results with field trials.

landscape refugia “Sites, locations, patches and stands (modelled) as more likely to persist in the face of climate change due to their sheltered position within the landscape, i.e., low likelihood of fire impact due to sheltered position, or reduced likelihood of drought stress due to aspect”⁸¹.

local native ecosystem “An ecosystem comprising species or subspecies (excluding invasive non-native species) that are either known to have evolved locally or have recently migrated from neighbouring localities due to changing climates. Where local evidence is lacking, regional or historical information can help inform the most probable local native ecosystems. While many ecosystems we consider natural have been modified in extent and configuration (e.g., through burning by Indigenous peoples). The term used to describe ecosystems in which local native species have been substantially transformed by humans well beyond natural analogues (e.g., agro-ecosystems) is ‘cultural ecosystem’”¹⁵⁸.

natural regeneration “Recovery or recruitment of species from in-situ propagules or propagules that have colonised a site without human intervention. Natural regeneration from these propagules can occur spontaneously or after facilitation other than direct human reintroduction of propag-

ules”¹⁵⁸.

neutral genomic variation Valuable background genetic/genomic variation within a population. Not attributed to a specific trait, but responsible for a species’ adaptive potential’. Natural selection acts on heritable variation within populations, and the genes present in the population vary through generations as the selective pressures change. Maintaining as much neutral variation as possible is important to maximise species’ resilience to future selection pressures not currently known. Retaining this neutral variation maintains a species’ adaptability, as there are many variants for selection to act on. The converse would be an adapted mono-genotype (i.e., a single banana cultivar), selected for one particular adaptive or valued trait yet with no variance in other traits that may confer resilience to disease. See adapted and adaptable seed sourcing.

pathogen Disease-producing organism, such as a fungus or a virus.

pest species ‘Pest’ is a subjective term often used to describe exotic or invasive insects, however, in this report it is used more generally for species (native or non-native) that negatively impact plant growth reserves by causing tissue damage or mortality. Due to shifting climatic suitability of trees and insect species, climate change may cause novel interactions among system components, meaning in some contexts we may manage a native insect species as a pest species due to the damage they risks they may pose to other values, i.e., mature forms of foundation tree species..

plant community types (PCTs) PCTs are historically recurring patterns of plant species assemblages that occur in relation to environmental conditions (soil parent type, temperature and precipitation regimes, and disturbance regimes). PCTs are defined by standard floristic composition, structure, habitat and locality.

provenance The “source (location) from which seed or other germplasm is derived”¹⁵⁸. Used in climate-adjusted provenancing, assumes genetic variation within a population, or local adaptation, or climatic-adaptation.

psyllids sap sucking insects of the order Hemiptera, severe infestation causes foliage damage and is associated with dieback events in several eucalypt forests.

rapid risk assessment team (RRAT) “A team deployed post-disturbance or upon the reporting of dieback to quickly evaluate damage to forest and ecosystem values to inform post-disturbance strategy”⁸¹.

recruitment The “production of a subsequent generation of organisms. This is measured not by numbers of new organisms alone (e.g., post-disturbance flushes of germinants or seedlings) but by the number that establish to adulthood in the population”¹⁵⁸.

reference ecosystem “A real or notional community of organisms able to act as a model or benchmark for restoration. A reference ecosystem usually represents a non-degraded version of the ecosystem, complete with its flora, fauna (and other biota), functions, processes and successional states that would have existed on the restoration site had degradation, damage or destruction not occurred—but should be adjusted to accommodate changed or predicted environmental conditions”¹⁵⁸.

reinforcement The management action of “increasing the numbers of a genetically limited plant or animal population, whether of a threatened or common species, to increase its potential for long-term conservation at a site”¹⁵⁸.

resilience (of a forest value) “The capacity of a system to absorb disturbance and re-assemble while still retaining similar function, structure”¹⁵⁸.

resist A management strategy/ pathway

where forest managers seek to maintain/restore a forest value based on pre-existing local native ecosystem, reference ecosystem, or pre-existing plant-community-type. From the Resist-Accept-Direct climate-adaptive management framework; synonymous with ‘planned mitigation’^{81, 130}.

risk The effect of uncertainty regarding a hazard or threat on management objectives or value. Risk is not necessarily negative; it may result in positive and negative outcomes, as well as opportunities and threats.

risk control A measure, action, or preparation attempting to maintain or limit escalation of a risk.

risk likelihood The chance (%) or probability(0-1) of a risk occurring.

risk owner The entity/ agency/ person accountable for identifying and managing the risk.

risk severity The magnitude of the negative outcome associated with a hazard impacting a value.

risk tolerance The levels of risk acceptable (through action or inaction associated with management of a value.

risk treatment A measure, action, or preparation attempting to reduce a risk.

state-and-transition models (STMs)

Conceptual/ diagrammatic model or tool used to describe the self-stabilising conditions of an ecosystem and the processes (i.e. disturbances, biotic or abiotic thresholds) that would result in transitions between stable states. STMs are usually annotated with available knowledge and evidence, but are able to incorporate hypothesized states and thresholds where evidence is unavailable. For this reason they are a valuable tool for mapping multiple possible futures, enabling preparation..

successional Temporal changes in vegetation structure and composition may be cyclic, i.e., recurring in the same place at different

times, or *successional*, where structure and composition shift through time.

threat/ threatening processes “A factor potentially or already causing degradation, damage or destruction”¹⁵⁸.

translocation “The movement of organisms/ communities from one part of the landscape or geographical area to another that is understood to be more suitable under future climates”¹⁵⁸.

vapour pressure deficit (VPD) Describes the drying power of air. It is similar to relative humidity but accounts for the water-holding capacity of air as it changes with temperature. Vapour pressure *difference*, describes the difference between the water vapour holding capacity of air when it’s saturated (Saturated Vapour Pressure; SVP) and the actual vapour pressure (AVP), the

amount of water vapour in the air at a given time. Air can hold more water as it heats up, a greater VPD translates to dryer air, and results in greater evapotranspiration rates, and greater water loss from plants to the atmosphere.

whole-genome sequencing (WGS)

Increasingly available and affordable, this type of sequencing involves reading and reassembly of longer sections of genetic material, and then assembly of the fragments in the correct order with respect to a reference genome. Whole-genome sequencing is necessary for the use of techniques like genome-wide association studies to hunt for genetic signatures associated with disease resistance across a population, and the use of landscape-genomic techniques to hunt for genetic variation associated with specific bioclimatic tolerances.

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Appendix A - Legislated Forest Values

This appendix outlines the legislated environmental values relevant to forest management planning. These values are derived from Commonwealth and State legislation and provide the foundation for risk assessment, prioritisation, and intervention in the context of dieback and climate succession. Each value is defined by its legal source and includes associated risks under changing climatic conditions.

Value	Definition	Climate-succession associated risks	Source
Species conservation	(a) a defined subspecies; (b) a taxon below a subspecies; (c) a recognisable variant; (d) a population of a species	Local loss of species and species extinctions due to loss of movement of species climatic range.	Biodiversity Conservation Act 2016 (NSW) Climate Change (Net Zero Future) Act 2023 (NSW) EPBC Act 1999 (Cth), s. 13.183
Species' Genetic Diversity and Evolutionary Potential	The variety of genetic information within and among populations of a species, and the capacity of those populations to adapt and evolve in response to environmental change. This includes the maintenance of genetic variation, gene flow, and evolutionary processes that underpin species' long-term survival and adaptability	Loss of genetic diversity and evolutionary potential increases vulnerability to climate change, fragmentation, and maladaptation, raising extinction risk. Small, isolated populations face inbreeding and reduced adaptability, while restoration efforts may fail if genetic variation is not maintained, undermining long-term species survival and ecosystem resilience under changing environmental conditions.	Biodiversity Conservation Act 2016 (NSW) National Parks and Wildlife Act 1974 (NSW)
Habitat protection	(a) Area periodically or occasionally occupied by a species or ecological community (b) Biotic and abiotic components of the area	Loss and degradation of habitat due to community composition and structural changes associated with changes in species climatic range	Biodiversity Conservation Act 2016 (NSW) EPBC Act 1999 (Cth)
Retaining Threatened Ecological Communities (TECs)	Threatened ecological communities (TECs) are legal entities that are independently listed under provisions	Loss and degradation of TECs as a result of asymmetrical climate impacts on factors that originally drove the formation of specific TECs	Biodiversity Conservation Act 2016 (NSW) EPBC Act 1999 (Cth)
Retaining ecological communities	An assemblage of species occupying a particular area	Loss and degradation of typified ecological communities because of asymmetrical climate impacts on factors that originally drove the formation of existing/recognised ecological communities.	Biodiversity Conservation Act 2016 (NSW)

Appendix A - Legislated Forest Values

Value	Definition	Climate-succession associated risks	Source
Retaining native vegetation	(1) any of the following types of plants native to New South Wales (a) trees (including any sapling or shrub or any scrub), (b) understory plants, (c) ground cover (being any type of herbaceous vegetation), (d) plants occurring in a wetland.	Refiltering of maladapted local native vegetation reduced competitive exclusion of undesirable coloniser species of threatened species are met at a site Species with specialist habitat needs at risk of declining habitat abundances and quality.	Local Land Services Act 2013 No 51 (NSW), s. 60B
Retaining remnant vegetation and protected regrowth	Native vegetation that was present prior to 1 January 1990 (or 1 January 1983 in the Western Division) is remnant. It also includes any vegetation that has regrown following unlawful clearing or clearing caused by bushfire, flood, drought or any other natural cause.	Refiltering of locally maladapted remnant native vegetation, increased pressures from undesirable coloniser species.	Local Land Services Act 2013 No 51 (NSW), s. 60B
Vegetation integrity	Degree to which composition, structure, and function of vegetation resembles a near-natural state	Changes in composition, structure and function due to vegetation instability, dieback and disturbance events.	Biodiversity Conservation Act 2016 No 63 (NSW), s. 1.5.2a
Habitat suitability	Extent to which habitat needs of threatened species are met at a site	Species with specialist habitat needs at risk of declining habitat abundances and quality.	Biodiversity Conservation Act 2016 No 63 (NSW), s. 1.5.2b

Appendix A - Legislated Forest Values

Value	Definition	Climate-succession associated risks	Source
Areas of outstanding biodiversity	Declared areas based on (a) the area is important at a state, national or global scale, and (b) the area makes a significant contribution to the persistence of at least one of the following— (i) multiple species or at least one threatened species or ecological community, (ii) irreplaceable biological distinctiveness, (iii) ecological processes or ecological integrity, (iv) outstanding ecological value for education or scientific research.	Value of localities based on species specific composition, habitat quality or vegetation structural characteristics at risk of degradation.	Biodiversity Conservation Act 2016 (NSW), S31
Soil stabilisation and erosion control	Conservation of the soil resources of the State, the mitigation of soil erosion and land degradation	High risk of increased erosion via degradation of vegetation condition and increased fire frequencies.	Soil Conservation Act 1938 (NSW) Local Land Services Act 2013 (NSW)
Nutrient cycling (carbon and water)	Conservation of ecosystems and ecosystem processes	At risk of destabilisation through increased disturbance regimes on composition, structure and function.	National Parks and Wildlife Act 1974 (NSW) s1.2A
Water catchment quality	a) protecting declared catchment areas, (b) protecting and enhancing the quality of water in declared catchment areas, (c) protecting controlled areas, (d) protecting and enhancing the quality of water in controlled areas.	Risk of impact on water quality from ecosystem degradation in catchment areas.	Water NSW Regulation 2020
(Forest) Production	The products of trees and other vegetation (other than timber) that are of economic value	At risk of impacts through impacts of increased disturbance frequencies and severities on growth and mortality in plantations, private and state forests.	Forestry Act 2012 (NSW) Regional Forest Agreements Act 2002 (Cth)

Appendix A - Legislated Forest Values

Value	Definition	Climate-succession associated risks	Source
Wilderness areas	(a) the area is, together with its plant and animal communities, in a state that has not been substantially modified by humans and their works or is capable of being restored to such a state, (b) the area is of sufficient size to make its maintenance in such a state feasible, and (c) the area can provide opportunities for solitude and appropriate self-reliant recreation.	At risk of degradation through climate-change, or loss of wildness if interventions are made to stabilise or restore with climate-adapted native species.	Wilderness Areas Act 1987 (NSW) No 196
World heritage areas	Includes national parks, forests and wilderness areas defined (in part) by the quality and condition of their vegetation (Australian World Heritage Database)	Locality-specific values are at risk of degradation through climatic range changes of resident species.	EPBC Act 1999 (Cth)
National heritage values	Includes numerous national parks, nature reserves and heritage places defined (in part) by the condition and integrity of their vegetation.	Locality-specific values are at risk of degradation through climatic range changes of resident species.	EPBC Act 1999 (Cth)
Cultural heritage	Objects (modified trees) and/or locations of cultural significance	At risk from species climatic range changes and increasing fire frequencies associated with climate change.	EPBC Act 1999 (Cth) Aboriginal and Torres Strait Islander Heritage Protection Act 1984 (Cth) National Parks and Wildlife Act 1974 (NSW)
Recreation	Enjoyment of the natural environment	At risk, through vegetation instability changes in quality, dieback associated hazards.	National Parks and Wildlife Act 1974 (NSW)

Appendix A - Legislated Forest Values

Value	Definition	Climate-succession associated risks	Source
Conservation of ecosystem types and components	To support biodiversity conservation in the context of a changing climate, to conserve biodiversity at bioregional and State scales, to slow the rate of biodiversity loss and conserve threatened species and ecological communities	Persistent climate-forcing presents a continent-wide risk to immobile and migratory biodiversity	Biodiversity Conservation Act 2016 (NSW)

Appendix B - Forest Management Assumptions Framework

Summary

A framework of forest management assumptions to support a structured review, either as an individual or in a group. The framework provides for each premise its original assumption, the emerging challenge posed by climate change, and a real-world example to illustrate its implications.

I. Ecological Stability and Predictability

Premise 1: Stationarity

Assumption - Native vegetation communities are self-regenerating and stable.

Challenge - Climate change disrupts climatic suitability, making some vegetation maladapted. Passive restoration may no longer be effective.

Example: Replanting historical species in degraded areas may fail if those species can no longer survive under new temperature or rainfall regimes, e.g., dieback in subalpine woodlands despite restoration efforts.

Premise 2: Predictability of Ecological Outcomes

Assumption - Management actions yield predictable ecological responses.

Challenge - Novel conditions and species interactions introduce high uncertainty. Adaptive, iterative approaches are needed.

Example: A prescribed burn intended to promote regeneration may instead favour invasive species or trigger unexpected mortality in native plants due to altered fire behaviour under hotter, drier conditions.

Premise 3: Confidence in Future Ecosystems

Assumption - We know what future ecosystems will look like.

Challenge - Multiple possible futures exist. Scenario planning and risk-averse strategies are essential.

Example: Restoration plans targeting a specific vegetation type may be undermined if climate models later suggest that type is no longer viable in the region, e.g., shifting from mountain ash to more drought-tolerant species.

Premise 4: Infrequent Large-Scale Degradation

Assumption: Environmental degradation is rare and limited in scale.

Challenge: Climate change increases the frequency, scale, and persistence of degradation.

Example: Repeated droughts and fires in close succession have led to widespread canopy collapse in Eucalypt forests, with little natural recovery observed over a decade.

II. Value Conflicts and Trade-offs

Premise 5: Alignment of Environmental Values

Assumption - Protected values (e.g., biodiversity, soil health, habitat quality) naturally align.

Challenge - Climate-driven instability may cause these values to diverge, requiring trade-offs and prioritisation.

Example: Fire suppression to protect threatened species habitat may conflict with the need for fire to maintain soil health or reduce fuel loads.

Premise 6: Conservation Based on Historical Species Assemblages

Assumption - Conservation targets based on historical species assemblages and distributions are appropriate.

Challenge - Novel ecosystems may require trait-based or function-based conservation targets.

Example: Conservation efforts focused on restoring historical alpine species may need to shift toward species with traits suited to warmer, drier conditions, e.g., drought-tolerant shrubs replacing cold-adapted trees.

III. Governance and Institutional Capacity

Premise 7: Stability of Governance and Institutions

Assumption - Governance structures and mandates remain stable.

Challenge - Climate change may shift public priorities, institutional capacity, and political will.

Example: A change in government policy may redirect funding away from long-term restoration projects toward short-term emergency response, disrupting continuity in forest management.

Premise 9: Adequate Resourcing and Legislative Efficacy

Assumption - Existing resources and laws are sufficient to protect environmental values.

Challenge - Stabilising maladapted ecosystems requires greater resources and more flexible legislation.

Example: Passive protection of remnant vegetation may be insufficient without active interventions like irrigation, pest control, or assisted migration, none of which may be covered under current legislation.

Premise 8: Controllable Risk Environment

Assumption - Risks to forest values can be managed or eliminated through regulation.

Challenge - Climate change introduces uncontrollable risks. Management must shift from prevention to mitigation.

Example: Regulatory controls on vegetation clearing may not prevent dieback caused by extreme heatwaves or pest outbreaks, requiring new strategies beyond traditional controls.

IV. Operational and Strategic Assumptions

Premise 10: Temporal Fit of Management Actions

Assumption - Management operates on time frames aligned with ecological processes.

Challenge - Climate transitions often outpace planning and funding cycles.

Example: A 10-year restoration plan may be rendered obsolete within 3 years due to rapid shifts in climate suitability or unexpected disturbance events.

Premise 11: Sufficiency of Existing Tools

Assumption - Current tools are adequate for climate adaptation.

Challenge - Many tools lack the capacity to model novel risks or validate emerging treatments.

Example: Vegetation mapping tools based on historical climate data may misidentify suitable restoration sites, leading to failed plantings and wasted resources.

Premise 12: Certainty in Scientific Knowledge

Assumption - Scientific knowledge provides clear guidance for action.

Challenge - Persistent uncertainty requires adaptive learning and precautionary approaches.

Example: Conflicting climate projections for a region may delay action, even though early intervention could reduce long-term risk.

Appendix C - Dieback and Climate Succession Risk Assessment

Summary

This protocol provides a practical, step-by-step approach for assessing and mitigating risks from dieback and climate succession. It is designed for use before or after large-scale impacts, supporting managers to reduce the likelihood and severity of persistent or irreversible damage to environmental values.

Quick Reference

- Use the checklist at each step to guide decision-making.
- Refer to local case studies for real-world applications.
- Adapt the process as new information and monitoring data become available.
- Do not be discouraged by the qualitative nature of estimates of magnitude, duration, probability, severity and risk. High degrees of uncertainty are a new feature of managing forests under climate change. Irrespective, this process enables the identification of available actions and their comparison of their relative merits.

Reviewing site-specific priority values

1. Identifying values

Values are defined in national, state, and local environmental legislation and further clarified through regulatory instruments. These protected values—such as species, habitats, ecological communities, and ecosystem functions - are embedded in estate legislation and planning frameworks (See: [Appendix A](#)). The purpose of these legal and regulatory layers is to ensure that specific environmental components, qualities, and processes are identified and safeguarded.

However, an implicit assumption within these frameworks is that values rarely conflict, either with one another or with secondary values like erosion control, vegetation structure, or ecosystem processes. This assumption is increasingly invalid in the context of climate change. Shifting climatic conditions are altering species distributions and community composition, creating asymmetrical impacts across landscapes. Some values may be irrecoverable in situ, while others may be more readily restored or translocated, leading to competition

between values.

This emerging complexity introduces ambiguity into management priorities, thereby increasing the risk of delayed or ineffective responses due to unclear accountabilities. Forest managers must now navigate these tensions by reassessing value hierarchies, identifying trade-offs, and developing adaptive strategies that reflect the realities of a changing climate.

2. Separating compound values

It is essential to carefully examine values that are defined and protected in compound terms.

Example: The Biodiversity Conservation Act 2016 (NSW) defines vegetation integrity (s.1.5.2a) as the “degree to which composition, structure, and function of vegetation resemble a near-natural state.” This definition assumes that composition, structure, and function are aligned and can be preserved together.

However, in the context of dieback and climate succession, this alignment may not hold.

Declines in locally climatically maladapted species may limit the ability to maintain original composition, while substitute species from outside the area may enable resilient restoration of structure and function. In such cases, it may be necessary to prioritise ex-situ conservation of displaced species and focus in-situ efforts on maintaining ecological processes and structural integrity.

To navigate these challenges—especially in triage scenarios—managers must assess risks to each component of compound values separately. This involves evaluating composition, structure, and function individually to determine their relative defensibility and potential for restoration. Such an approach enables the development of pragmatic value hierarchies under worst-case scenarios, based on the recoverability of each component.

Value-by-Value Climate-Associated Risk Assessment

Climate succession introduces a range of novel and destabilising risks to forest values (See: [Appendix A](#)). To manage these risks effectively, forest managers must assess both the severity and probability of climate impacts on each value.

atypical disturbance events, they are now early indicators of potential climate maladaptation.

1. Assessing Severity of Consequences

Severity should be evaluated across two dimensions: magnitude and duration of impact.

1. Magnitude of Impact:

- (a) Localised impacts
- (b) Landscape-scale impacts
- (c) Regional-scale impacts
- (d) Multi-region impacts
- (e) Generalised impacts

2. Duration of Impact:

- (a) Short term (months to years)
- (b) Medium term (years to decades)
- (c) Long term (decades to centuries)
- (d) Persistent (irreversible)

Refer to [Figure 14](#) for a visual matrix illustrating consequence severity.

2. Assessing Probability of Impact

At scale, probability estimates tend to translate to a percentage of extent impacted by the hazard. The main tools for estimating the probability of impact are:

- **Observed sensitivity:** Rather, contemporary dieback events being treated as one-off

- **Projected climate estimates:** such as the [NarClim 2.0](#) interactive climate projections map.
 - **Known narrow bioclimatic tolerances and high disturbance sensitivity:** Such as narrowly-distributed specialist species (See: [Subsection 3.9](#))
 - **Narrow distributions and modelled vulnerability:** Such as those provided by ecological niche and refugia models (See: [Subsection 3.9](#))
- adequate¹⁷⁰.
- Life history sensitivity. Several obligate re-seeding species have already been shown to become locally extinct when the fire recurrence interval is shorter than the time to reproductive maturity¹⁷¹.

High confidence and precision estimates of risk probabilities are not possible. Given the persistent high uncertainty arising from emission scenarios, spatial distributions of future temperature and moisture regimes, unknowns regarding system components and their interactions when perturbed, we should be wary of managing towards a single specific future or an average future.

Despite this, coarse quasi-qualitative estimates of risk probability still provide a valuable roadmap. Coarse estimates of differences in risk allow managers to articulate condition thresholds in advance, put in place monitoring that will enable tracking of changes in condition, and enable preparations for management actions when thresholds are crossed.

Importantly, given that risk assessments are used to develop management strategies based on condition thresholds, the accuracy of probability estimates during this process is less critical than risk awareness, preparation and improved monitoring infrastructure to keep track of changes in condition.

Examples:

- Hydraulic traits are tightly coordinated with site aridity. Many Australian species operate close to their hydraulic thresholds across the moisture spectrum, making them vulnerable to intensifying droughts and elevated vapour pressure deficits (VPD). Increased VPD raises atmospheric drying power, reducing plant water content and increasing fire risk, even when soil moisture is

- Resprouting capacity is a key resilience trait. Species with epicormic or basal resprouting ability are better equipped to recover from canopy collapse and disturbance. The location and resilience of meristematic buds significantly influence post-disturbance regeneration^{2,10}. However, epicormic-resprouter species also have a threshold fire recurrence interval associated with failure or resprouting^{79,80}.
- Species at the edge of their climatic distribution face heightened risk of maladaptation and population fragmentation. Dominant eucalypts have shown sudden, severe dieback under extreme drought and heat events, especially in areas with shallow soils and declining groundwater levels¹⁷².

CONSEQUENCE SEVERITY		MAGNITUDE (EXTENT)				
		Localised impacts	Landscape-scale impacts	Regional-scale impacts	Multiple Regions	Generalised
		<1%	1-10%	10-25%	25-90%	>90%
DURATION	Short term (months to years)	Insignificant	Minor	Minor	Moderate	Major
	Medium-term (Interannual-decadal, i.e., ENSO)	Minor	Moderate	Moderate	Major	Major
	Long-term (decades-centuries, multiple ENSOs)	Moderate	Moderate	Major	Major	Catastrophic
	Persistent (Irreversible)	Moderate	Major	Major	Catastrophic	Catastrophic

RISK MATRIX		SEVERITY OF CONSEQUENCE				
		Insignificant	Minor	Moderate	Major	Catastrophic
PROBABILITY	Remote (0-10%)	LOW 1	LOW 5	LOW 8	MEDIUM 14	MEDIUM 16
	Unlikely (11-40%)	LOW 2	LOW 6	MEDIUM 12	MEDIUM 14	HIGH 21
	Possible (41-60%)	LOW 3	LOW 7	MEDIUM 13	HIGH 19	HIGH 22
	Likely (61-90%)	LOW 4	MEDIUM 10	HIGH 17	HIGH 20	SEVERE 24
	Highly Likely (91-100%)	MEDIUM 9	MEDIUM 11	HIGH 18	SEVERE 23	SEVERE 25

Figure 14. Top: An illustrative consequence severity analysis matrix for use in dieback and climate succession risk assessments. Severity is evaluated along two dimensions: duration and magnitude. Magnitude is depicted qualitatively and spatially here, though quantitative scales (e.g., 0–100%) may be more appropriate for some values. **Bottom:** An example risk assessment matrix for scoring both the unmitigated risk to a given value and the residual risk after applying a hierarchy of controls. Climate succession introduces a novel risk environment, making risk mitigation a priority. For each threatened value, both the magnitude of impact and the probability of occurrence are assessed. By implementing a hierarchy of controls, the aim is to reduce residual risk as much as possible. However, due to the location-specific nature of some values, some level of persistent residual risk may be unavoidable.

Dieback and Climate-Succession Risk Assessment							[Template v1 8/10/25]
Site							
Date:							
Risk assessment participants:							
Value: Species x							
Value tiers	Probability of impact (0-100%)	Severity of consequence ¹	Current Risk to tier	Hierarchy of risk controls ³		Risk-control owner	Residual risk rating ²
BEST CASE: Existing distribution, extent and genetic diversity, in existing locations.	Highly Likely	Moderate	HIGH 18	SUBSTITUTE	Climate-adaptive/ genomically informed restoration (in situ)		HIGH 17
				ISOLATE	Firebreaks		
				ENGINEER	Stand density, terraforming, fuel reduction		
				ADMIN	Condition monitoring Rapid response restoration		
				ASSET PROTECTION	Active defense, Irrigate, insulate, and herbicide.		
TRIAGE: Most existing distribution, restored extent in appropriate locations, all genetic diversity.	Likely	Major	HIGH 20	SUBSTITUTE	Assisted migration to restore extent in new suitable locations		HIGH 17
				ISOLATE	Assisted migration to protect species from extreme conditions		
				ENGINEER			
				ADMIN			
				APCs			
WORST CASE: Refuge distributions, all genetic diversity.	Possible	Catastrophic	HIGH 22	SUBSTITUTE			MEDIUM 16
				ISOLATE	Conservation of existing diversity in seedbanks and seed production areas (ex-situ)		
				ENGINEER			
				ADMIN	Landscape genomic analysis - map genetic space across geographic distribution, assess genotype/ environment associations, predict environmental niche, validate in ongoing restoration programs. Vulnerability phenotype surveys mapping and modeling		
				ASSET PROTECTION	Direct defense of buffers.		

Value: Vegetation structural integrity							
Value tiers	Probability of impact to tier (0-100%)	Severity of consequence ¹	Current Risk to tier	Hierarchy of risk controls ³ Colored by risk-tiers they target		Risk-control owner	Residual risk rating ²
BEST CASE: Existing structural intensity in existing locations.	Highly likely	Moderate	HIGH 18	SUBSTITUTE			HIGH 17
				ISOLATE	Firebreaks		
				ENGINEER	Stand density, terraforming to improve hydration, fuel reduction		
				ADMIN	Condition monitoring Rapid response restoration		
				ASSET PROTECTION	Active defense of mature plants from fires Irrigate, insulate, and herbicide.		
TRIAGE: Existing structure in some places, restored structure in degraded places	Highly likely	Major	SEVERE 23	SUBSTITUTE	Climate-adaptive/ genomically informed restoration (in situ) Assisted migration to restore structure with mix of cooccurring resilient species, CAP/ Genomically informed species, and anticipated future species, mixing fast growing and slow growing.		HIGH 19
				ISOLATE	Assisted migration to suitable locations to improve persistent in future.		
				ENGINEER	Terraforming to improve establishment success		
				ADMIN	Ongoing field trials to assess establishment and survival of genotypes across changing interannual conditions.		
				ASSET PROTECTION	Defend restoration plantings to aid establishment		
WORST CASE: Long-term discontinuity of mature woody species	Likely	Catastrophic	SEVERE 24	SUBSTITUTE	Restore existing sites with a mix of cooccurring resilient species, CAP/ genomically-informed species, and anticipated future species, mixing fast growing and slow growing.		MEDIUM 16
				ISOLATE	Fire buffers around revegetation zones.		
				ENGINEER			
				ADMIN	Landscape genomic surveys to inform restoration. Vulnerability surveys mapping and modeling		
				ASSET PROTECTION	Direct defense of trials with fire containment buffers.		

Figure 15. Illustrative Dieback and Climate Succession Risk Assessments for two values. The goal of risk assessment and mitigation is to reduce either the probability or severity of hazardous interactions between climate and environmental values. Importantly, since values may no longer be consistently aligned, it is best to conduct this process on a value-by-value basis, allowing for interventions to protect specific values to vary accordingly. In an uncontrolled risk environment, risks to some location-specific values may not be reduced through management actions, while for others, available actions may mitigate risks substantially.

Appendix D - Resist-Accept-Direct Management Pathways

Managing forests through climate change is unfamiliar and may seem unapproachable in complexity. However, there are only so many values, and only so many management actions available to mitigate impacts to them, and many management actions protect several values at once. For these reasons, the task of developing mitigation strategies that consider all values simultaneously yet mitigate risks individually is both necessary and possible.

The matrices below show Resist– Accept– Direct (RAD) management pathways mapped to legislated forest values under three climate succession scenarios of increasing severity, considered for both intact and degraded sites available for revegetation. Pathways are evaluated at both the local (site-specific) and global

(across the full extent of each value) scales. In best-case scenarios, all values are weighted equally; under triage and worst-case scenarios, values are prioritised based on differences in sensitivity, recoverability, and practical management constraints.

The matrices illustrate the varied application of RAD pathways according value condition and resilience. Direct pathways are only considered during the restoration of degraded sites. The matrix continues with additional forest values on the following pages. Note, for some irrecoverable and defensible values, our tolerance for degradation may remain low at all times, and so Accept and Direct pathways may never be appropriate.

Value	BEST CASE SCENARIO 'Stay the course'		TRIAGE SCENARIO 'Adapt the course'		WORSE-CASE SCENARIO 'Reimagine the course'	
	Retain all values in existing locations.		Retain all values in fewer locations, protect core values, restore degraded values in suitable locations.		Protect refuges, protect core values, restore degraded values in suitable locations.	
	Site type		Site type		Site type	
	Existing intact communities	Degraded/ ready to restore	Existing intact communities	Degraded/ ready to restore	Existing intact communities	Degraded/ ready to restore
Recreation	Resist degradation of recreational values.	Accept areas of lower recreational value.	Direct – Adjust recreational use of natural areas based on changing suitability.		Direct – Adjust recreational use of natural areas based on changing suitability.	
Timber Production	Resist declines in global production using altered ecological thinning, HR burns altered harvest cycles	Resist declines in production through restoration with CAP/ genomically informed seed lots.	Accept temporary global declines in production.	Direct – Restore production using cooccurring unaffected species, CAP/ genomically informed seed lots, or climate-adapted species.	Direct – Transition production to cooccurring resilient species, CAP/ genomically informed seed lots, or climate-adapted species. Adjust and optimize global output for new climate regimes.	Direct – Iteratively improve production using CAP/ genomically informed species and climate-adapted species.
Existing wilderness areas	Resist local degradation of wilderness value by limiting management intervention.	Accept vegetation change following disturbance, provided signs of self regeneration and invasive species exclusion remain. Accept interventions to reduce bushfire risks.	Accept reduction of local wilderness extent due need to mitigate large-scale fires.	Accept local community transitions in degraded wilderness areas provided they don't impact core values.	Accept local reduction on local wilderness extent due need to mitigate large-scale fires.	Direct – Intervene to prevent impacts on core values.
Site specific biodiversity & heritage values	Resist local declines in site-specific values through development or clearing, defend against disturbances using fires services and buffers	NA	Resist – Protect remnant value individual protection measures where necessary.	Resist declines in value due to local species compositional shifts, intervene to prevent catastrophic state transition, restore and preserve and protect remnant value.	Resist – Protect remnant value individual protection measures where necessary. Accept unavoidable site-specific declines compositional values are at severe risk of degradation, with limited interventions available.	Direct – Intervene if necessary to prevent impacts on core values.

Value	BEST CASE SCENARIO 'Stay the course'		TRIAGE SCENARIO 'Adapt the course'		WORSE-CASE SCENARIO 'Reimagine the course'	
	Retain all values in existing locations.		Retain all values in fewer locations, protect core values, restore degraded values in suitable locations.		Protect refuges, protect core values, restore degraded values in suitable locations.	
	Site type		Site type		Site type	
	Existing intact communities	Degraded/ ready to restore	Existing intact communities	Degraded/ ready to restore	Existing intact communities	Degraded/ ready to restore
Species' distributions	Resist declines in extent through clearing or development in species abundance.	Resist – restore and improve extent in areas previously cleared.	Resist - Retain as much as possible existing species distributions Accept local losses of some maladapted species to novel local conditions.	Direct maladapted species to degraded sites at mild edges of distribution – assisted migration	Resist - Protect refuge locations of viable scale. Accept local losses of maladapted species to due to novel local conditions.	Direct degraded sites toward restoration of other impact values, using with climate-adjusted foundation species. Direct – Restore global extent through translocation/ assisted migration to suitable climates.
Existing Plant Community Types.	Resist degradation of existing mature PCTs by limiting clearing and development.	Resist – restore PCTs extent previously lost through clearing by revegetation with preexisting species.	Resist degradation of remnant local declines through protection against clearing and development. Resist PCT state transitions with engineering interventions to reduce exposure to stressors.	Resist – Resist compositional shift by revegetating with genomically-informed provenances of existing local species. Resist state-transitions through fortification with locally resilient co-occurring species. Accept declines in extent and some compositional shifts/ fortify with translocated native species.	Resist PCT loss in naturally resilient locations. Accept – unavoidable PCT extent declines/ degradation in some locations.	Direct degraded sites toward restoration of other impact values, using with climate-adjusted foundation species. Direct – Restore extent through translocation/ assisted migration.

Value	BEST CASE SCENARIO 'Stay the course'		TRIAGE SCENARIO 'Adapt the course'		WORSE-CASE SCENARIO 'Reimagine the course'	
	Retain all values in existing locations.		Retain all values in fewer locations, protect core values, restore degraded values in suitable locations.		Protect refuges, protect core values, restore degraded values in suitable locations.	
	Site type		Site type		Site type	
	Existing intact communities	Degraded/ ready to restore	Existing intact communities	Degraded/ ready to restore	Existing intact communities	Degraded/ ready to restore
Ecosystem services (i.e., nutrient, carbon and water cycling)	Resist degradation of existing ecosystem services by limiting clearing and development.	Resist – restore ecosystem function previously lost through clearing, by revegetation with preexisting species.	Resist actions that impact intact ecosystem services. Resist rapid global declines in ecosystem services through interventions that resist with engineering interventions	Direct - Mitigate risk of prolonged reductions in ecosystem services discontinuity by restoration of degraded sites using a balance of resilient local species, climate-adapted provenances, climate-anticipated and/or displaced, species.	Resist – Protect pre-existing ecosystem in refuges. Resist rapid global declines in ecosystem services through interventions that resist rapid loss of ecosystem services with engineering interventions	Direct – Mitigate risk of prolonged reductions in ecosystem services discontinuity by restoration of degraded sites using a balance of resilient local species, climate-adapted provenances, climate-anticipated and/or displaced, species.
			Accept temporary loss and declines of existing ecosystem services due to climate succession		Accept temporary loss and declines of existing ecosystem services due to climate succession. Intervene to protect core values to preserve site condition.	
Habitat quality and suitability	Resist degradation of existing habitat limiting by clearing and development.	Resist – Restore habitat previously lost through clearing, by revegetation with preexisting species.	Resist declines in local habitat suitability and quality due to clearing. Delay rapid declines by alleviating stressors on foundation species.	Direct – Mitigate risk of prolonged habitat discontinuity by restoration of degraded sites using a balance of resilient local species, climate-adapted provenances, climate-anticipated and/or displaced, species.	Resist declines in local habitat suitability and quality due to clearing. Delay rapid declines by alleviating stressors on foundation species.	Direct – Mitigate risk of prolonged habitat discontinuity by restoration of degraded sites using a balance of resilient local species, climate-adapted provenances, climate-anticipated and/or displaced, species.
			Accept unavoidable impacts on habitat quality due to maladaptation/ dieback.		Accept unavoidable impacts on habitat quality due to maladaptation/ dieback	
			Direct - Where possible, translocate organisms to suitable habitat.		Direct - Where possible, translocate organisms to suitable habitat.	

Value	BEST CASE SCENARIO ‘Stay the course’		TRIAGE SCENARIO ‘Adapt the course’		WORSE-CASE SCENARIO ‘Reimagine the course’	
	Retain all values in existing locations.		Retain all values in fewer locations, protect core values, restore degraded values in suitable locations.		Protect refuges, protect core values, restore degraded values in suitable locations.	
	Site type		Site type		Site type	
	Existing intact communities	Degraded/ ready to restore	Existing intact communities	Degraded/ ready to restore	Existing intact communities	Degraded/ ready to restore
Living cultural heritage objects & landscapes	Resist – Protect living cultural heritage objects and landscapes. Resist – Protect all living cultural heritage objects and landscapes,	NA	Resist – Direct defense (IPMs) of living cultural objects and landscapes and buffers. Preserve and record character off site.	NA	Resist – Direct defense (IPMs) of living cultural objects and landscapes and buffers.	NA
			Accept some unavoidable impacts to climate-vulnerable vegetation in cultural heritage landscapes.		Accept – Accept impacts to climate-vulnerable vegetation in cultural heritage objects and landscapes.	
Species genetic diversity	Resist losses by characterising and quantifying local uniqueness and limiting against clearing etc.	Resist – Preserve regional genetic distinctness by revegetation with local seed.	Resist – Preserve locally adapted resilient genotypes. Conserve evolutionary potential offsite in seed banks and replicated seed production areas.	Resist – Assuming climate-succession risk outweighs maladaptation risk - restore with adapted and adaptable seed lots.	Resist – Preserve locally adapted resilient genotypes. Conserve evolutionary potential offsite in seed banks and replicated seed production areas.	Resist - Use adapted and adaptable seed lots which conserve evolutionary potential to vegetate suitable locations (assisted migration)
			Accept local losses of maladapted genotypes/ population.	Accept mixed survival as maladapted genotypes fail to establish/ survive.	Accept declining extent of some local genotypes due to climate/ disease selection.	Direct – Consider using degraded sites to trial or protect/ restore displaced species from other regions.
Soil conservation	Resist – Monitor and stabilize using existing local vegetation.		Resist – Monitor and stabilize in all locations using any native vegetation		Resist – Monitor and stabilize in all locations using any native vegetation.	

Appendix E - Substitution Controls

Substitution controls are interventions that reduce risk by replacing vulnerable, maladapted, or declining system components with alternatives that are more resilient to current or projected future climate conditions. In the risk hierarchy, substitution controls are particularly relevant during restoration or revegetation of degraded sites, where the persistence of pre-existing species or communities is unlikely under future climate scenarios. Substitution can involve the introduction of new genetic material, species, or provenances, and is a proactive strategy to maintain ecosystem function and services in the face of climate-driven change.

Types of Substitution Controls

1. Climate-Adjusted Provenancing

Definition: Climate-adjusted provenancing (CAP) involves sourcing and planting seed from populations that are better adapted to projected future climates, rather than relying solely on local provenance.

Examples:

- The [Restore and Renew](#) project (Royal Botanic Gardens Sydney) provides tools for selecting seed sources based on climate projections and genetic diversity¹⁷³.
- CAP is increasingly recommended in restoration guidelines (e.g., [Flora-bank](#), [Climate-ready revegetation guide \(AdaptNSW\)](#)) to improve resilience of plantings to future drought, heat, and disease pressures.

2. Fortification During Restoration

Definition: Skewing species composition in restoration projects towards those that have demonstrated resilience to recent disturbances or climate extremes.

Example:

- The [Monaro Comeback](#) project (NSW) responded to *Eucalyptus viminalis* dieback by planting a mix of unaffected co-occurring eucalypt species alongside climate-adapted provenances of *E. viminalis*, providing insurance against future dieback events.

3. Assisted Migration and Species

Translocation **Definition:** Moving species or populations to areas outside their historical range that are projected to become suitable under future climates^{155,156,174}.

Examples:

- [Guidelines for the Translocation of Threatened Plants in Australia \(2018\)](#) provide a framework for risk assessment and planning.
- [Translocation Operational Policy \(NSW\)](#) provides a framework for planning, assessing, and implementing translocations of threatened species. This policy applies to both plants and animals and is designed to ensure that translocation projects are scientifically justified, well-planned, and likely to succeed.

4. Restoration with Adaptable Seed Lots (Admixture Provenancing)

Definition: Using seed mixes that maximise genetic diversity, including both locally adapted and non-local genotypes, to increase the adaptive potential of restored populations^{157,160}.

Example:

- Ongoing field trials compare the establishment and survival of local, climate-adjusted, and admixture seed lots across multiple sites and years^{175–178}.

Effectiveness and Limitations

Substitution controls can significantly reduce the risk of restoration failure and ecosystem collapse by increasing the likelihood that some individuals or species will thrive under future conditions.

Their effectiveness is maximised when:

- Informed by landscape genomics, trait surveys, and ecological niche modelling.
- Integrated with monitoring and adaptive management to track survival, growth, and ecosystem function.

- Supported by robust seed sourcing, record-keeping, and stakeholder engagement.

Limitations include:

- Uncertainty about future climate trajectories and species' adaptive capacity.
- Potential for maladaptation, outbreeding depression, or invasive behaviour in translocated species.
- Regulatory and social barriers to moving species outside their historical range.

Recommendations for Forest Managers

- **Assess site suitability and risk:** Use ecological niche modelling and trait surveys to identify which species or provenances are likely to be resilient under future conditions.
- **Diversify restoration strategies:** Combine local, climate-adjusted, and admixture seed lots to spread risk and maximise adaptive potential.
- **Monitor and adapt:** Track survival, growth, and ecosystem function in restored sites, and adjust seed sourcing and species selection as new data emerge.
- **Engage stakeholders:** Communicate the rationale and risks of substitution controls to landholders, regulators, and the public to build support for innovative approaches.
- **Follow best-practice guidelines:** Use national and international standards for seed sourcing, translocation, and restoration^{158–160}

Translocation Establishment Trials

Translocation restoration trials are vital for testing methods like climate-adjusted and genomically-informed provenancing, providing direct comparisons of seed lots from various sources to see which species are most resilient in current conditions.

Figure 16 illustrates that while these trials offer valuable data on seedling establishment and short-term survival, their broader significance requires careful interpretation. Short-term metrics, such as seedling survival and growth rates, may not reliably predict long-term ecosystem resilience, as rapidly growing

seedlings can be less robust over time. High gene flow in some species, as in many eucalypts, can obscure the benefits of climate-matched seed sources, and year-to-year environmental variability can dramatically affect results. Therefore, ongoing monitoring and adaptive management are crucial, as single-year outcomes may not reflect long-term success.

These insights are essential for Australian forest managers and restoration practitioners aiming to enhance ecosystem resilience under changing climates^{175,177–179}.

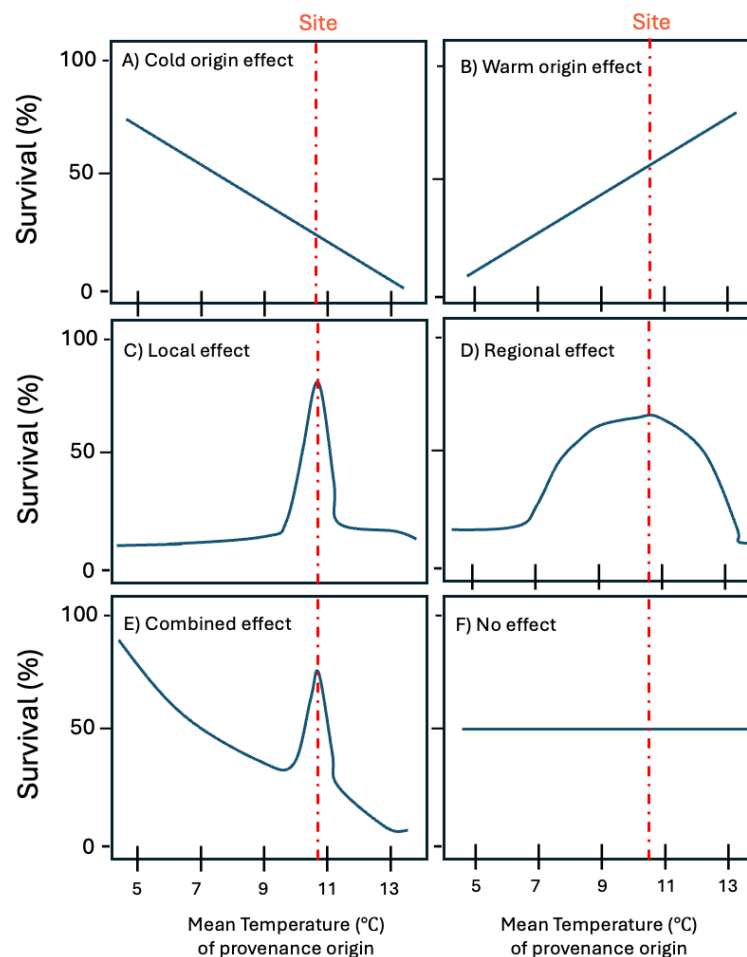


Figure 16. Illustrative outputs from a translocation restoration trial. Figure adapted from Kraus et al. (2024)¹⁷⁹.

Trials within Ongoing Restoration Efforts

Ongoing restoration efforts face persistent high risks due to significant uncertainty about future climates and the unknown factors that influence species distribution. Existing revegetation approaches restoring sites using species from existing ecological communities are increasingly vulnerable to climate maladaptation. To address these challenges, it is essential to diversify restoration strategies and actively monitor their outcomes.

Implementing coordinated, side-by-side trials of different strategies across multiple sites and years provides the only reliable way to test predictions for suitability and establishment success. This approach requires tightening the restoration seedling stock pipeline, from seed collection through to planting. For exam-

ple, systematically mapping the genetic diversity of key foundation species, continually updating suitability predictions using new climate models, and enhancing industry standards for seed lot tracking—by linking GPS and genomic data of mother trees to individual seedlings and tracking their field survival—would embed adaptability within restoration practices.

Assuming some individuals mature from this diversified trial approach, it also helps mitigate the risk of losing the long-term values associated with mature tree species in each location. By initiating the early establishment of slow-growing, climate-resilient species, we increase the chances that restored habitats will remain robust and valuable in the face of ongoing environmental change.

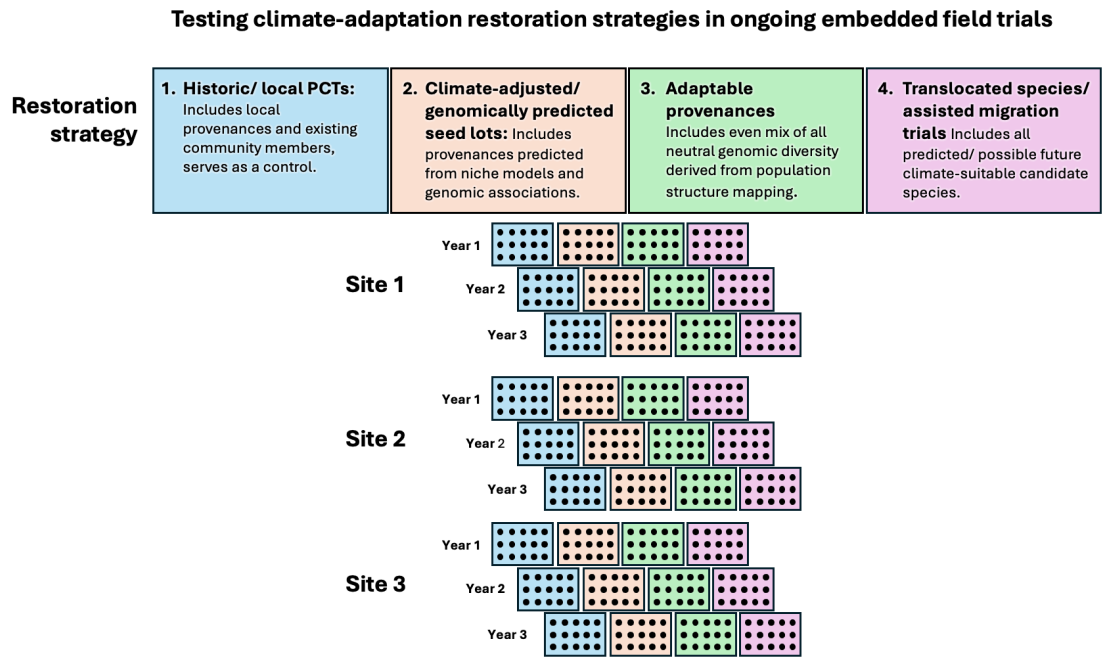


Figure 17. Illustration of coordinated establishment trials within ongoing restoration efforts. While this may seem complicated, there is a finite list of species likely to be suited to any given site, and a finite list of strategies for using them. In all cases, performance needs to be compared with the existing species from the local ecological community, meaning the traditional restoration strategy is also maintained.

Appendix F - Isolation Controls

Isolation controls are interventions that reduce risk by separating or protecting key ecosystem components, such as genetic resources, populations, or habitats, from exposure to climate-driven hazards or threatening processes. In the risk hierarchy, isolation controls are particularly valuable for safeguarding evolutionary potential, rare species, or critical ecosystem functions when in situ protection is no longer feasible or when ex-situ conservation offers a strategic buffer against loss.

Types of Isolation Controls

1. Ex-Situ Conservation: Seed Banks, Seed Libraries, and Seed Production Areas

Definition: Collecting, storing, and maintaining genetic material (e.g., seeds, spores, tissue cultures) from across a species' range to safeguard evolutionary potential and provide resources for future restoration^{148,180,181}.

Examples:

- The Australian National Seed Bank is the national seed banking platform
- Regional seed production areas (SPAs) are increasingly used to ensure a reliable supply of genetically diverse seed for large-scale restoration and climate-adapted plantings (e.g., [Mt Annan, NSW](#), [Cumberland Plain, NSW](#), [Lurg Hills, VIC](#), [Hunter Valley, NSW](#), [Euroa, VIC](#)).

2. Assisted Migration to External Refugia

Definition: Moving populations or genetic material to locations outside their current range that are projected to remain suitable under future climate scenarios, effectively isolating them from emerging threats.

Examples:

- Assisted migration is being trialled for threatened plant species with limited dispersal capacity, using ecological niche modelling and genetic surveys to identify suitable recipient sites.
- The NSW and national translocation guide-

lines provide frameworks for risk assessment, site selection, and monitoring (See: [Translocation Operational Policy \(NSW\)](#)).

3. In situ Isolation: Refugia Identification and Protection

Definition: Identifying and prioritising the protection of landscape, population, or habitat qualities (e.g., topographic, historic climate refuges, remnant mature stands, hydrological, or microclimatic refugia) that buffer populations from climate extremes or disturbance^{62,137,182}.

Examples:

- [Climate Refugia NSW](#) and similar tools are used to map and prioritise internal and external refugia for threatened species and ecological communities.
- Management actions may include targeted fire protection, pest exclusion, or hydrological interventions to maintain refuge conditions.

4. Genetic Rescue and Population Reinforcement

Definition: Introducing genetic material from other populations to increase genetic diversity and reduce inbreeding depression in isolated or declining populations.

Examples:

- Genetic rescue has been used for threatened plant and animal populations, with careful assessment of genetic compatibility and adaptive potential.

Effectiveness and Limitations

Isolation controls are highly effective for safeguarding irreplaceable genetic resources, rare species, and critical ecosystem functions, especially when in situ persistence is unlikely.

Their effectiveness is maximised when:

- Guided by robust genetic, ecological, and spatial data.
- Integrated with monitoring and adaptive management to track survival, reproduction, and genetic diversity.
- Supported by clear protocols for seed col-

lection, storage, and use.

Limitations include:

- High resource requirements for collection, storage, and long-term maintenance.
- Potential loss of local adaptation or ecological function if populations are isolated from their original environment.
- Regulatory and ethical considerations for moving species or genetic material outside their historical range.

Recommendations for Forest Managers

- Prioritise ex-situ conservation for species or populations at high risk of local extinction or with limited dispersal capacity.
- Use genetic and ecological data to guide seed collection, storage, and use in restoration and reinforcement projects.
- Identify and protect in situ refugia using spatial modelling and ground surveys, and integrate refugia management into broader

adaptation strategies.

- Follow best-practice guidelines for translocation and genetic rescue, including risk assessment, stakeholder engagement, and long-term monitoring.
- Integrate isolation controls with substitution, engineering, and administrative controls for comprehensive risk management.

Appendix G - Engineering Controls

Engineering controls are interventions that manipulate components of the environment, or the environment itself, to reduce hazardous interactions and mitigate risks to forest values. In the risk hierarchy, engineering controls are more direct than administrative controls, aiming to physically alter stand structure, fuel loads, hydrology, or pest/disease dynamics to increase ecosystem resilience or reduce the severity of dieback and climate-driven impacts.

Types of Engineering Controls

1. Ecological Thinning Ecological thinning reduces stand density to alleviate competition for water and resources, aiming to increase resilience to drought and other stressors. While widely used in production forestry, its application in native forests is still being evaluated.

Examples:

- Long-term thinning trials in River Red Gum (NSW), Box-Ironbark woodlands (VIC), and Jarrah and Karri forests (WA) are well positioned to assess improved drought resilience and survival of thinned forests following extreme events^{183–185}.
- The WA Forest Management Plan 2024–2033 includes thinning up to 8,000 ha annually to reduce aridity stress and mortality in regrowth forests and mining rehabilitation areas^{186,187}.

2. Fire Management

Hazard-Reduction Burning

Increasing the frequency and strategic placement of hazard-reduction burns can reduce fuel loads and the risk of catastrophic fire in fire-sensitive ecosystems. Despite operational familiarity, ongoing assessment is needed to ensure hazard-reduction burning is effective under changing climate conditions and does not have unintended ecological impacts¹⁸⁸.

Cultural Burning

Cultural burning refers to the use of fire by First Nations peoples, applying traditional knowledge and practices to manage country for cultural, ecological, and community ob-

jectives. Cultural burning is typically low-intensity, patchy, and timed to local conditions, aiming to promote ecosystem health, protect cultural sites, and reduce the risk of severe wildfires. There is growing recognition of the value of cultural burning in contemporary forest management, with collaborative projects underway in many regions of Australia.

Key distinctions:

- Hazard-reduction burning is primarily focused on reducing fuel loads for asset protection and wildfire risk mitigation.
- Cultural burning is holistic, integrating ecological, cultural, and social values, and is led or co-designed by Traditional Owners.

Recommendations:

- Where possible, integrate cultural burning practices into fire management strategies, in partnership with Traditional Owners and local Indigenous communities.
- Monitor and evaluate both hazard-reduction and cultural burning for their effectiveness in reducing risk and supporting ecosystem resilience.

3. Earthworks and Terraforming

Earthworks, such as contour banks, swales, or bog stabilisation, are used to reduce erosion, increase water retention, and stabilise soils, especially during restoration of degraded land or post-fire recovery.

Example:

- Subalpine bog stabilisation projects in the Brindabella Ranges, ACT, have demon-

strated the value of using coir logs to limit erosion and maintaining hydrological function and reducing erosion risk following the 2003 and 2019/20 bushfires.

4. Biological Controls

Biological control involves manipulating pest or pathogen populations to limit their impact on vulnerable trees.

Examples:

- The introduction of the parasitoid wasp *Anaphes nitens* has successfully controlled the *Gonipterus* weevil in eucalypt plantations, reducing dieback risk¹⁸⁹.
- Mating signal disruption by jamming chemical signals (pheromones) during mating windows of threatening pest insect species using targeted local release of synthetic

pheromones^{190,191}.

- Ongoing research is exploring the potential for low-impact biocontrols to protect native forests from pest outbreaks exacerbated by climate change⁷⁰.

5. Restoration for Resilience

Engineering controls are often integrated into restoration projects to enhance resilience:

- Neutral genetic diversity-based resilience: Including diverse seed sources to maximise adaptive potential.
- Community diversity-based resilience: Bio-diverse plantings to buffer ecosystem services.
- Trait-based resilience: Selecting species with traits conferring fire, drought, or pest resistance.

Effectiveness and Limitations

Engineering controls can provide substantial risk reduction, especially when implemented proactively and at appropriate scales. Their effectiveness is maximised when:

- Applied in stands or landscapes where stress is density-dependent, or disturbance risk is high.
- Supported by robust monitoring and adaptive management.
- Integrated with administrative and operational controls.

Limitations include:

- Potential for unintended ecological impacts (e.g., loss of habitat complexity, off-target effects).
- High resource requirements for implementation and monitoring.
- Variable effectiveness depending on site conditions and disturbance regimes.

Recommendations for Forest Managers

- Assess site suitability for engineering controls, considering stand structure, species composition, and disturbance history.
- Prioritise proactive interventions in areas at high risk of dieback, drought, or fire.
- Integrate engineering controls with administrative and operational strategies for comprehensive risk management.

- Monitor and evaluate outcomes to refine interventions and avoid unintended consequences.
- Engage stakeholders and communicate risks and benefits to build support for active management.

Appendix H - Administrative Controls

Administrative controls are interventions that change how we manage forest values to reduce hazardous outcomes. They operate through policies, procedures, planning, training, and monitoring, rather than direct physical intervention. In the risk hierarchy, administrative controls are essential for embedding best practice into daily operations, ensuring consistent and coordinated responses across landscapes and organisations. Their effectiveness depends on strong leadership, clear communication, and ongoing compliance monitoring.

Types of Administrative Controls

1. Regulatory and Management Plan Review

Regular review and updating of legislation, regulatory instruments, and management plans is critical to ensure they reflect emerging risks from dieback and climate succession. Many existing plans were developed under assumptions of ecological stability and may not address large-scale, climate-driven change. Iterative review processes allow for the integration of new knowledge, risk assessments, and adaptation priorities.

2. Access and Hygiene Protocols

Policies such as permits, vehicle wash-downs, and hygiene procedures are mandated in many Australian states to prevent the spread of pathogens like *Phytophthora cinnamomi*. For example, the Western Australian Department of Biodiversity, Conservation and Attractions (DBCA) requires dieback hygiene stations and access restrictions in national parks and reserves, significantly reducing pathogen spread in high-value conservation areas.

3. Operational Planning and Zoning

Spatial planning tools are used to identify and map dieback risk zones. In Fitzgerald River and Stirling Range National Parks (WA), administrative controls include exclusion zones,

seasonal access restrictions, and scheduling of works during low-risk periods. This approach minimises disturbance and pathogen introduction in sensitive habitats.

4. Training and Awareness

Ongoing training for staff and contractors on dieback identification, hygiene, and reporting is standard practice in many agencies. For example, NSW Environmental Trust projects have delivered targeted training to local councils and restoration groups, improving early detection and rapid response to new outbreaks.

5. Monitoring and Reporting Systems

Administrative controls underpin systematic monitoring and reporting of dieback and climate succession impacts. Project Dieback (WA) established a centralised database for mapping infestations and tracking management actions, enabling adaptive management and transparent reporting to stakeholders.

6. Policy Integration

Dieback and climate succession risk management is now embedded in state and regional conservation strategies, bushfire management plans, and environmental approvals. This ensures that administrative controls are consistently applied across projects and land tenures.

Effectiveness and Limitations

Administrative controls are highly scalable and cost-effective, providing a foundation for other risk management actions. Their success depends on:

- Strong leadership and institutional support
- Clear communication and compliance monitoring
- Integration with operational and engineering controls

While administrative controls cannot eliminate risk, they have proven effective in slowing the spread of disease-associated dieback, supporting rapid response, and integrating climate adaptation into routine land management. However, they must be regularly reviewed and adapted to remain effective in a rapidly changing risk environment.

Examples:

- *Phytophthora* Dieback (WA): Implementation of hygiene protocols, access restrictions, and mapping in Priority Protection Areas has maintained dieback-free status in high-value sites and is considered a model for collaborative, evidence-based intervention. For example, the use of exclusion zones and seasonal access restrictions by Fitzgerald River and Stirling Range National Parks has minimised disturbance and pathogen introduction in sensitive habitats¹⁹².
- NSW Environmental Trust Projects: Targeted training and monitoring systems have improved early detection and response to dieback events, informing broader management guidelines.

Recommendations for Forest Managers

- Regularly review and update management plans to reflect current climate risk assessments and adaptation strategies.
- Implement and enforce access and hygiene protocols in all dieback-prone areas.
- Invest in staff and contractor training to ensure early detection and rapid response to dieback and climate succession events.
- Establish robust monitoring and reporting systems to track the effectiveness of interventions and inform adaptive management.
- Integrate administrative controls with operational and engineering controls for a comprehensive risk management approach.

Appendix I - Rapid Dieback, Damage and Recovery Assessment (RDDRA)

Summary

Dieback has historically been infrequent and unpredictable. As a result, responses have tended to be reactive, delayed and inconsistent. Research-led investigations often take years, meaning management advice arrives after the best intervention window has passed. The RDDRA provides a practical, time-bound process to characterise impacts quickly and guide proportionate action¹⁷¹.

Why rapid assessment matters

- Short intervention windows: Opportunities to stabilise values can close within weeks to months after disturbance.
- Scale and uncertainty: Climate-driven events occur across large areas and trophic levels; fine-scale causal resolution is rarely feasible on useful time frames.
- Consistency and defensibility: Standardised steps enable repeatable assessments, clear triggers and transparent decisions.

Illustrative example: Victorian Ash Forests

To minimise type change after severe fire, the Victorian Government established two specialist teams: a Rapid Risk Assessment Team to map mature/immature ash extent and fire history, and a Rapid Response Recovery Team to conduct tactical damage and recovery as-

sessments (extent, severity, seed availability, seedbed receptivity, residual live trees, landscape context, practicability, refugia, provenance and forest values). An operations unit then implemented recovery and monitoring using a decision tool. Timeliness was critical: effective reseeded needed to occur within roughly 4–5 months post-fire to align with winter dormancy breaking, spring germination and a receptive ash bed^{81,193}.

What an RDDRA delivers

A disturbance generalised protocol that rapidly surveys the essential, decision-relevant features of a dieback event; extent, severity, likely drivers, self-recovery potential and value risk—so managers can select an appropriate Resist–Accept–Direct (RAD) pathway and apply the hierarchy of controls. The detailed, step-wise RDDRA checklist follows in the next section.

RDDRA: Stepwise Guidance

1. Identification of Affected Species

Purpose: Establish which species and populations are affected, and what their conservation status and provenance imply for management.

Guidance:

- Inventory all affected and unaffected species and subspecies, noting threatened status and known provenances
- Place the affected population(s) in the context of the broader species distribution (range, regional strongholds, refugia)
- Characterise populations' genetic/ genomic structure/ variation across the species' range; note clustering by region/latitude (if data available).
- Assess isolation by distance: is the affected population exchanging genes with neighbouring, unaffected populations?
- Note any and all co-occurring species that are unaffected.

2. Severity Assessment

Purpose: Develop some **0–100% severity indices** that capture key dimensions of forest health and resilience, enable comparison of severity of impacts across sites and time, and inform trigger points. Not all dieback warrants intervention. Native forests possess inherent resilience; concentrate resources where thresholds and values justify action.

Guidance:

- **Within-tree severity** - Define transparent, field-ready classes, e.g.,
0 = no impact;
1 – 10 = light canopy stress;
11–40 = moderate defoliation/smaller branch dieback;
41–70 = severe canopy loss, entire stem dieback;
71–90 = extensive mortality;

91–100 = near/complete stand loss)

- **Within-stand severity** - Define transparent, field-ready classes to describe the degree of affected individuals at a site or per unit area, i.e., % of trees surveyed or stems affected per ha.
- **Severity across age classes** - Does dieback affect only one age class?
 - Pay attention to life history interruptions - Did the dieback impact all reproductively mature individuals? This may be an indicator of the impending collapse of the local seed bank.
 - Pay attention to recruit health - Are there still healthy individuals from younger size classes, or are the young plants being killed as well? If there are healthy immature forms, perhaps restoration interventions are unnecessary. Conversely, if all size classes are being impacted, it may be an indicator of imminent community-state transition and an urgent need for intervention.
- **Severity across microclimate gradients** - Is dieback patchy and/or concentrated on specific topographic features (i.e., elevation, aspect)? These remnant patches may reflect naturally sheltered and potential climate refugia due to microclimate or topographic conditions (radiation, temperature, moisture, substrate depth, etc.)
- **Local variation within species**- Is there variation in susceptibility among similar-aged trees within 100m of each other? Given that seed dispersal in eucalypts is limited to 100m, variation in dieback severity at small distances may be an indicator of a genetic basis to resilience, microclimate differences at small scales, or reflect randomness of exposure to the dieback causal agent.
- **Within-community severity** - Are there

co-occurring unaffected species? These may have traits conferring resilience to the dieback driver; they are important for continuity of structural habitat and should form the foundation for any restoration efforts.

3. Mapping Impact Extent

Purpose: Define where impacts are occurring, how extensive they are, and how quickly they are changing, to support triage and causal inference. Early extent mapping is valuable. In progressive events, identifying an active dieback front enhances opportunities for manipulative tests and establishes a robust baseline beyond the front. RDDRA may be repeated; establish methods early so spatial expansion can be tracked consistently.

Guidance:

- **Spatial Mapping – coarse to fine-scale**
Make a coarse assessment of scale: individual trees, isolated stands, patch scale, landscape/regional, or distribution wide. Use evidence streams available at practical time scales, such as:
 - Area manager input: contact forest managers in other jurisdictions
 - Ground and road transects - Note the GPS coordinates of specific locations to enable efficient follow-up.
 - Aerial surveys
 - Spatial correlations with topography (aspect, elevation, slope, soil depth, height above drainage) and bioclimatic variables (temperature, moisture)
 - Remote-sensed changes in greenness (defoliation/canopy browning) validated by field surveys – Sentinel2-based metrics^{9,65,71,194–196}.
- **Temporal Mapping**
Make a coarse assessment of onset and speed: rapid (weeks–months) or gradual (years–decades)
 - Record first public reports and first agency confirmation

- Identify coarse temporal correlations between spatial onset and extreme events, allowing for legacy and compound stresses that can delay visible impacts

- **Tenure Mapping**

Make a list of tenures and estates affected; these affect the resourcing pipelines for restoration

- Private land (agricultural, urban, etc.)
- Local council/Crown land
- National Park or nature reserve
- State forest
- National Heritage site
- World Heritage site

Have the relevant stakeholders been notified?

4. Causality Assessment

Purpose: Determine whether understanding mechanisms will improve decisions, and, where feasible, identify plausible drivers to guide targeted controls or forward risk modelling.

Guidance:

- **When useful**
 - Enables targeted interventions (e.g., biotic controls)
 - Improves predictive power (e.g., hydraulic vulnerability informing future exposure)
- **Caveats**
 - Complex trophic interactions and interdependencies often limit clean attribution; many studies find correlations rather than definitive causes because manipulative experiments in mature forests are rarely feasible.
 - Where systems show signs of self-recovery, detailed causal resolution may add little; where mortality indicates maladaptation to climate, proceed to intervention planning

- **Illustrative mechanisms**

- Drought-weakened trees become more vulnerable/”nutritious” to pests (e.g., *Phoracantha semipunctata* can irrupt markedly during heatwaves and drought.)
- Synchrony between tree dehydration and insect emergence can amplify outbreaks, especially in multi-year droughts (e.g., snow gum impacted by *Phoracantha mastersi*^{11,70}).
- Warming can increase insect activity, lengthen seasons, expand distributions, and increase generations per season/ year; native parasitoids may respond out of step with pest species to drought/season length, altering regulation.

- **Minimum information for management**

- Compile a plausible factor inventory (climate stress, pests/pathogens, soil/hydrology, fire, browsing) sufficient to identify recovery pathways and screen feasible controls
- Record evidence quality (field observation, remote sensing correlation, experiment, expert judgment)

5. Self-Recovery Assessment

Purpose: To assess whether the system is likely to recover without intervention, and whether key life history stages are intact.

Guidance:

- Are cohorts reaching reproductive maturity? (e.g., obligate reseeders such as ash species typically need 15–20 years post-fire before seed bank replenishment; high fire frequency can interrupt replenishment)
- Is recruitment occurring after disturbance (healthy seedling emergence and survival)?
- Do causal agents (e.g., herbivorous insects or pathogens) target all life stages, risking cohort collapse and local extinction?

- Are unaffected co-dominant or functionally equivalent species present to maintain ecosystem processes?
- Are there unaffected patches of forest that may serve as habitat refugia, and do these need to be managed defensively to limit habitat discontinuity?

6. Revisit Value-based Risk Assessment and Triggers

Purpose: Reassess priority values, risk ratings and decision triggers considering observed damage.

Guidance:

- Do updated severity and extent cross pre-agreed decision thresholds for management action?
- Do results change the defensible/indefensible/restorable status of values?
- Are existing RAD management goals and strategies (Resist/Accept/Direct) still appropriate?
- Is the existing hierarchy of controls to limit risks to values still appropriate?

7. Review Available Response Pathways

Purpose: Select and sequence feasible pathways, ideally pre-mapped in management plans through scenario planning with stakeholders. Options.

Guidance:

- Unassisted recovery – monitor and protect from additional stress
- Resist (planned mitigation) – defend in situ values (e.g., targeted pest control, micro refugia protection)
- Accept (allow autonomous adaptation) – enable transition where resistance is infeasible or low return
- Direct (planned adaptation) – guide com-

position/function toward future suitable states

- Mixed defence – deploy a hierarchy of values approach (defend irreplaceable; accept or direct elsewhere)

8. Review Practical Constraints

Purpose: Confirm feasibility given jurisdictional, scale and resource limitations.

Guidance:

- Tenure constraints – approvals, obligations, cross-boundary coordination
- Impact scale – site/patch vs landscape; implications for logistics and monitoring design
- Resourcing for interventions – implementation and ongoing maintenance
- Resourcing for monitoring – baseline, indicators, frequency, data management and reporting.

Appendix J - Asset Protection Controls

Asset protection controls (APCs) are a risk control that involve protecting individual assets (i.e., trees or small patches of exceptional cultural or ecological significance) from exposure to hazards. Notably, this approach is equivalent to 'Personal Protective Equipment (PPE)' in workplaces. PPE is considered the least-effective and least-scalable mode of risk reduction. For this reason, APCs are best suited to small areas where the values at risk justify the investment. Despite this, active defence of limited refugia or remnant mature vegetation patches may be critical in minimising discontinuity in habitat.

Types of APCs

1. Targeted Insulation, Irrigation and Fire Protection

During extreme droughts, irrigation of high-value or culturally significant trees has been used to alleviate water stress, fire damage, and prevent mortality. Insulation of trunks and asset protection using fire-fighting services are other methods to protect mature stands from ground fire, particularly in areas with exceptional ecological or cultural value. Firebreaks/containment lines located to improve the defensibility of high-value assets may also be considered an APC.

2. Chemical and Biological Controls

Injection of high-value trees with phosphite or insecticides has been effective in protecting against pest insects or pathogen outbreaks. Where available, these interventions must be carefully managed to avoid off-target impacts, especially in systems with threatened insectivorous species.

3. Biosecurity and Monitoring Integrated pest management in Australian agriculture and forestry includes robust biosecurity measures (e.g., restricting movement of soil and equipment, cleaning vehicles, and monitoring pest populations). These practices have reduced the introduction and spread of dieback-causing or-

ganisms and improved the resilience of managed sites.

Example:

- *Phytophthora* Dieback Management in WA includes strict quarantine and hygiene protocols, targeted application of phosphite injections to high-value trees, and physical barriers to prevent pathogen spread. These measures have successfully limited the spread of dieback in biodiversity hotspots, protected threatened species, and enabled mining and rehabilitation activities to proceed with reduced ecological impact.

Recommendations for Forest Managers

- Asset Protection is most effective when applied to small, high-value areas where the benefits justify the cost and effort.
- Asset Protection is likely to fail when challenged with high-magnitude stressor events. Success depends on rigorous planning, monitoring, and adaptation to site-specific risks.
- While not a substitute for landscape-scale management, APCs will likely be an important tool to buy time for threatened species and ecosystems, mitigate discontinuity of slow-to-restore forest values, support restoration, and protect irreplaceable assets.

Appendix K - Dieback and Climate Succession Network (DCSN)

About

The Dieback and Climate Succession Network (DCSN), established in 2024, is an interdisciplinary, voluntary network of professionals focused on research and coordinated responses to vegetation dieback and climate-driven change in Australia. The DCSN evolved from the High-Country Dieback Network (HCDN, est. 2020), which provided a platform for researchers, restoration practitioners, and state environment departments to share knowledge and coordinate efforts across multiple dieback systems, including Snow gum (ACT, NSW, VIC), Ribbon gum (NSW), Blakely's Red gum (ACT), Montane ash (VIC), and Stringy bark (SA). As the HCDN broadened its scope, the DCSN emerged to foster wider collaboration with established research groups and management systems nationwide. The network now has over 120 participants from six states and two territories. These diverse case studies offer valuable opportunities to improve local management responses and outcomes.

Aims

The DCSN aims to foster collaboration and knowledge exchange among researchers, land managers, restoration NGOs, and state environment departments to accelerate the uptake and development of effective responses to dieback and climate-driven vegetation change in Australian ecosystems. Sudden and chronic dieback events, as well as ongoing climate-driven succession, are increasing in frequency and severity. Addressing these complex, large-scale challenges requires a transdisciplinary approach, bringing together expertise from research, policy, and operational practice. Close coordination of effort and resources is essential to maintain ecosystem structure and function, and to avoid unintended or perverse outcomes.

Monthly Seminars and Meetings

The DCSN meets virtually every month. Meetings include introductions, updates, and 1–3 presentations, typically covering:

- Research updates, proposals, and case studies from forest and woodland dieback systems and ecosystem change across Australia.
- Mechanisms: Interactions between physiology, environmental and genetic variation, and dieback processes.
- Dieback and ecosystem mapping: Remote sensing, soil and hydrology, long-term monitoring, and ground truthing.
- Mitigation and restoration: Ex-situ seed banking, seed production areas, population genomic surveys, climate-adapted provenance trials, and reciprocal transplant trials.
- Management and policy: Climate-adaptive management and governance frameworks, such as the Resist–Accept–Direct, Value–Rules–Knowledge adaptation frameworks, and risk-based frameworks.

The network encourages plain language explanations, constructive and critical feedback and translation of research, management, and policy. Student participation and manager feedback on projects in development are strongly encouraged, as this input often enhances the impact and practical value of research and highlights new opportunities for collaboration and more effective translation of network members' efforts to positive outcomes for forested landscapes.

Participating in the DCSN

To join the Dieback and Climate Succession Network, use the QR code below. You will receive advance notice of upcoming speakers and events. You can also indicate your interest in presenting your work at a future network meeting.

