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Permanent Native Carbon Forests from Radiata Pine Plantations

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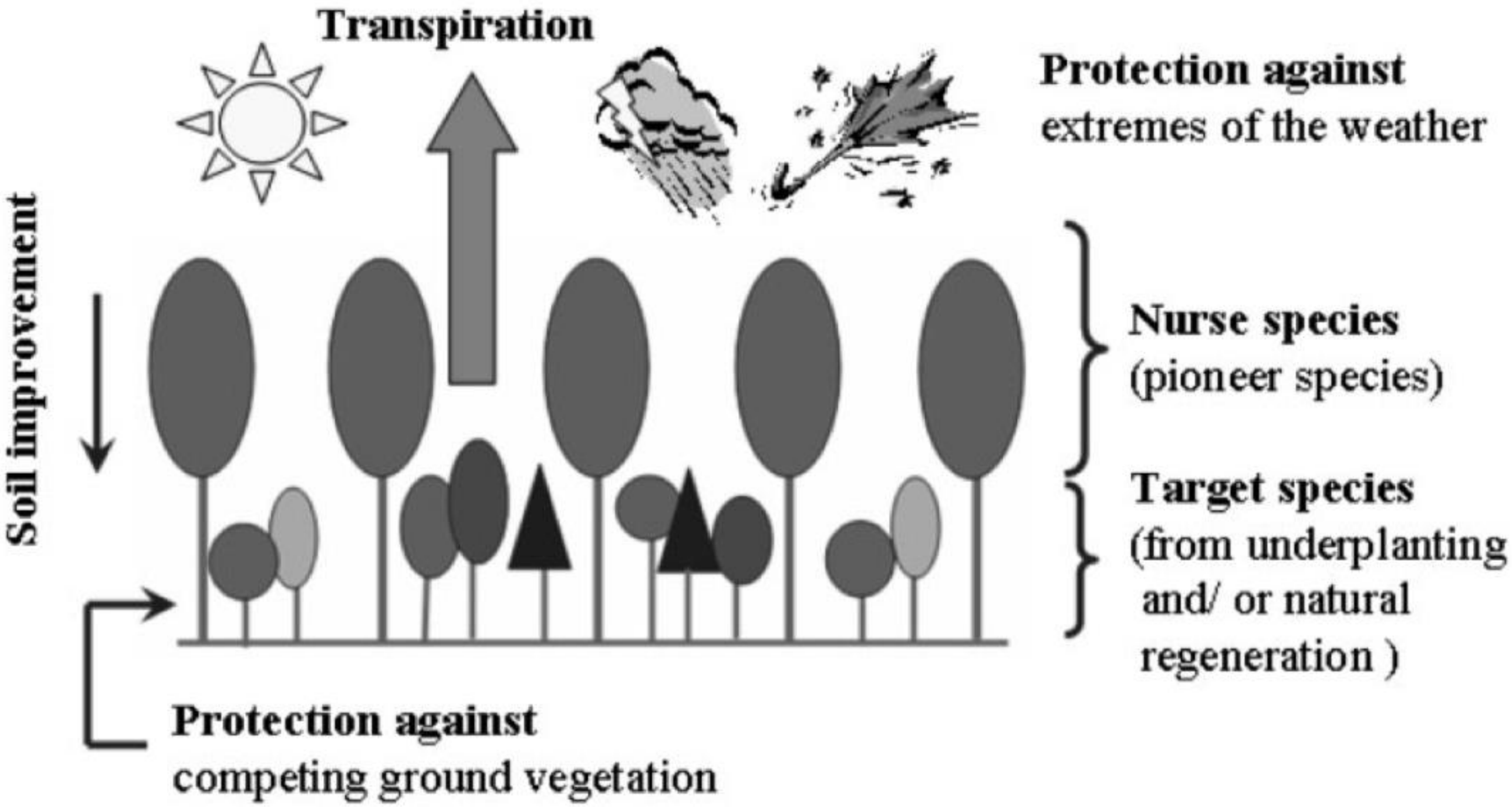
Talk Outline

- Radiata pine plantations as a nurse crop
- Ecological issues and principles for managing radiata pine for permanent forestry
- Optimising radiata pine plantations specifically for permanent carbon forestry
- Further research

Nurse Crop Concept

- Partial shading
- Suppression of light-demanding weeds
- Restored forest regeneration function



Pommerening & Murphy 2004 *FORESTRY*

Nurse Role of Radiata Pine Plantations

- Fast-growing tree
- Rapidly dominates the site and modifies the microclimate
- Starting point for permanent forestry
- Radiata pine is a relatively short-lived tree – a succession is essential
- Transition to a self-sustaining forest

Applications for Transitioning Pines to Permanent Native Forest

Soil conservation

- Avoid clearfell on erodible soils
- Rapid transition of pines
- Large-scale forest restoration

Forest restoration

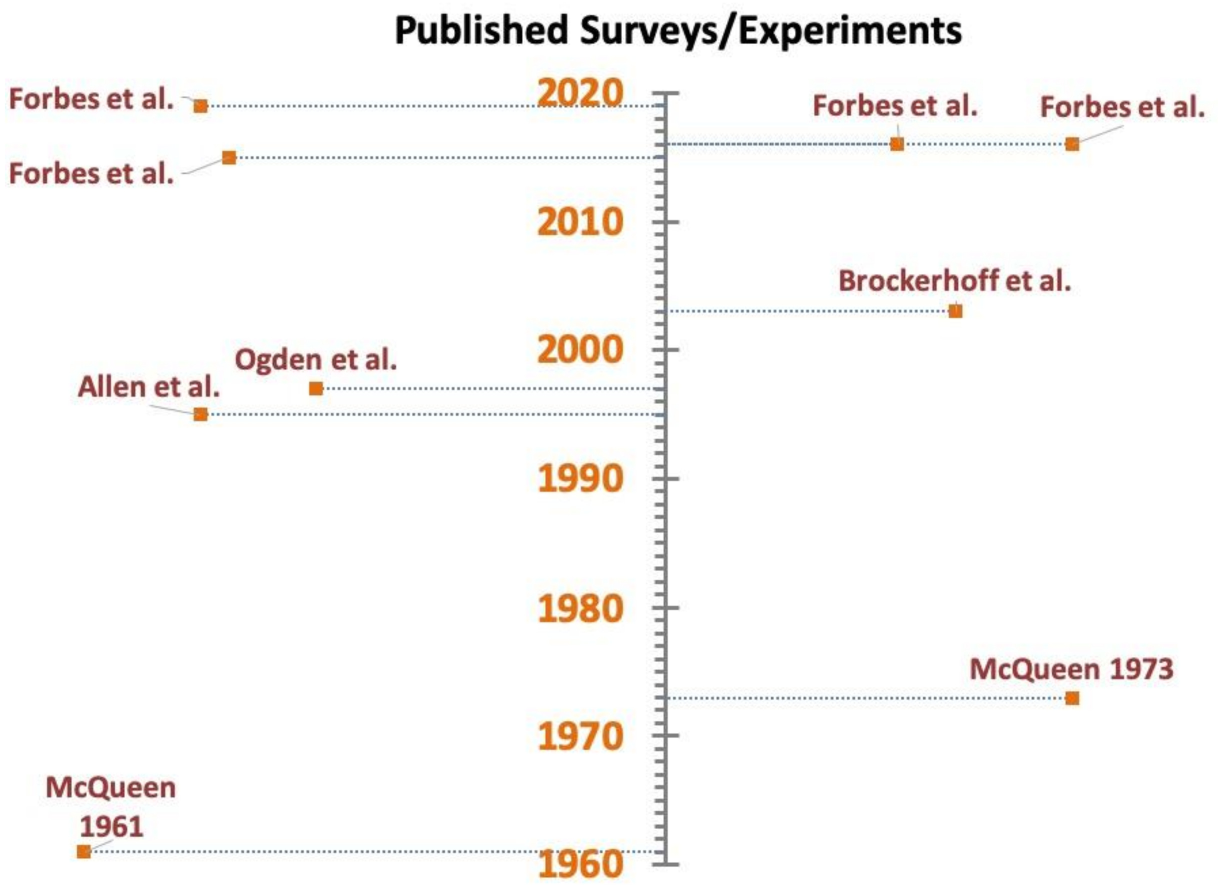
- Use the forest microclimate to create diverse naturalised forest

Carbon storage

- Rapid-biomass nursery for recruitment of high-biomass, long-lived trees

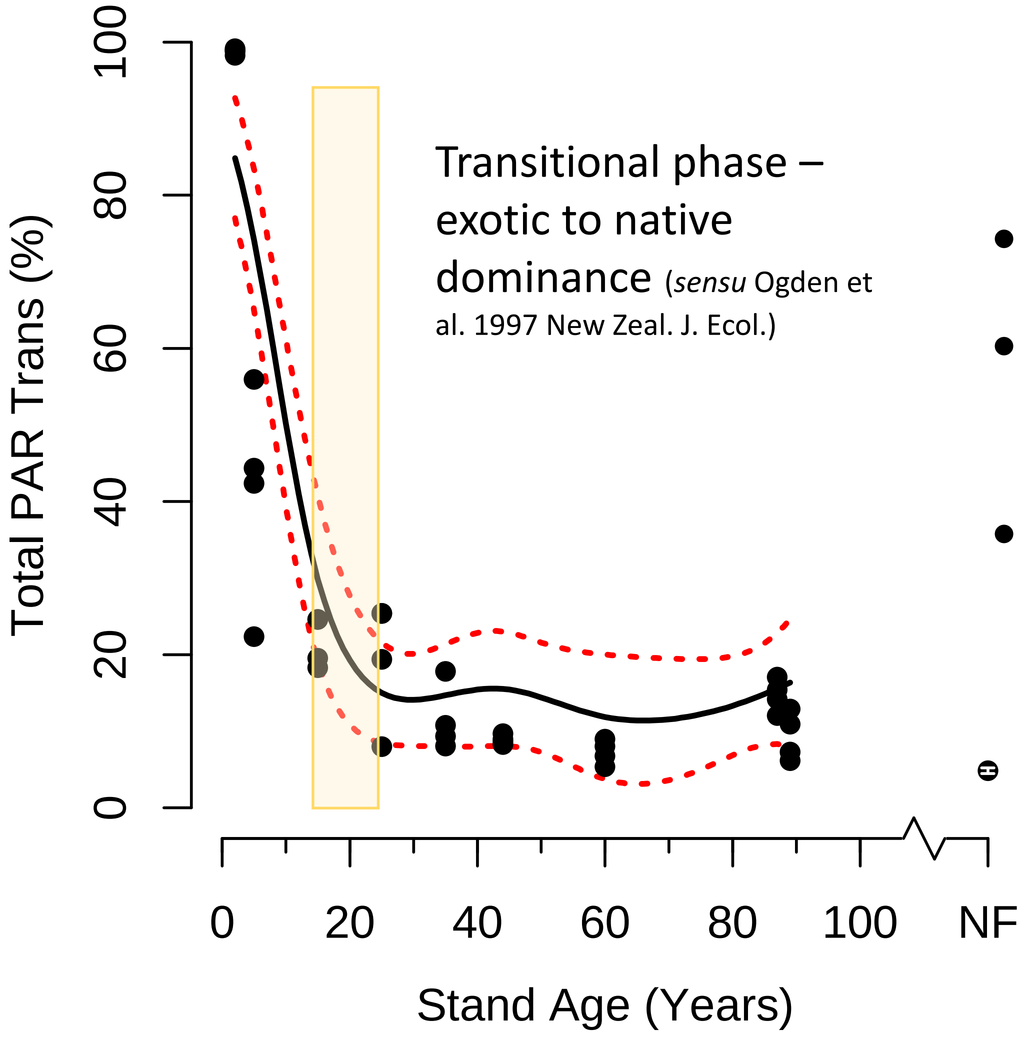
Key Variables for Understorey Regeneration and Reverting Pines

- **Stand age/structure and light** (McQueen, Ogden et al., Allen et al. Brockerhoff et al.)
- **Climate (geographic variance)** (Brockerhoff et al.)
- **Interventions** (Forbes et al.)
- **Seed source proximity** (Forbes et al.)
- **Herbivory** (Forbes et al. and the ecological literature)



Ecological Issues and Principles

Stand Structure and Understorey Light Environment



Forbes et al. 2019. *NEW ZEAL J FOR SCI*

- Stand structure controls understorey light environment which drives understorey regeneration
- Stand age drives stand structure
- Light environment needs to exclude light-demanding and favour shade-tolerant species
- Aside from age, canopy and understorey manipulations can help to achieve regeneration of shade-tolerant forest flora

Increasing shade tolerance

Increasing seed size

Increasing stature

Increasing longevity

2–5 yrs.



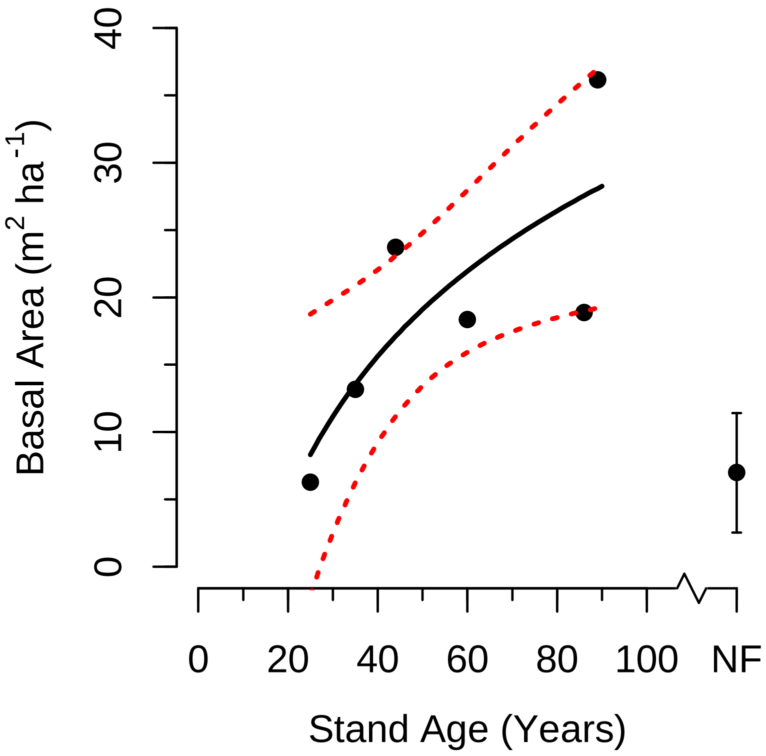
15–25 yrs. +






Forbes et al. 2019. *NEW ZEAL J FOR SCI*

Both the pine canopy and the developing understorey can cause too much competition for light



Forbes et al. 2016. *RESTOR ECOL*

Forbes et al. 2016. *FOREST ECOL MANAG*

Competition Interventions

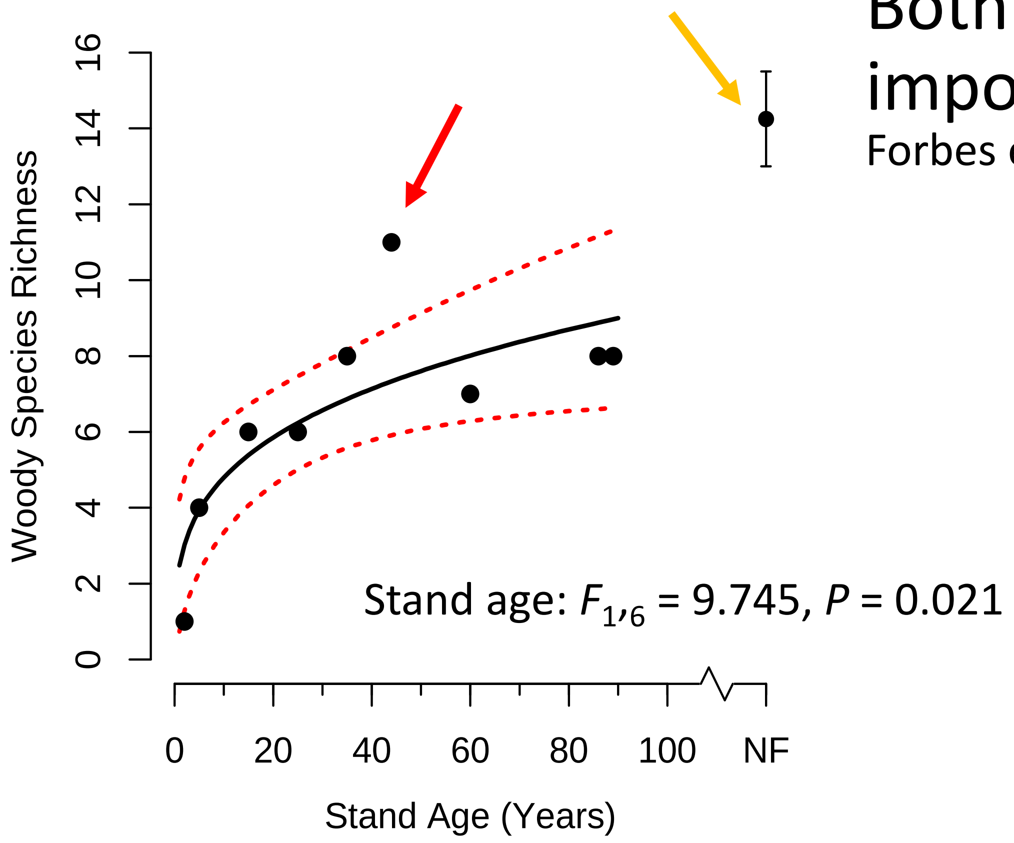
Before & After Canopy Gap Creation

Forbes et al. 2016. *RESTOR ECOL*

Before & After Tree Fern Thinning

Forbes et al. 2016. *FOREST ECOL MANAG*

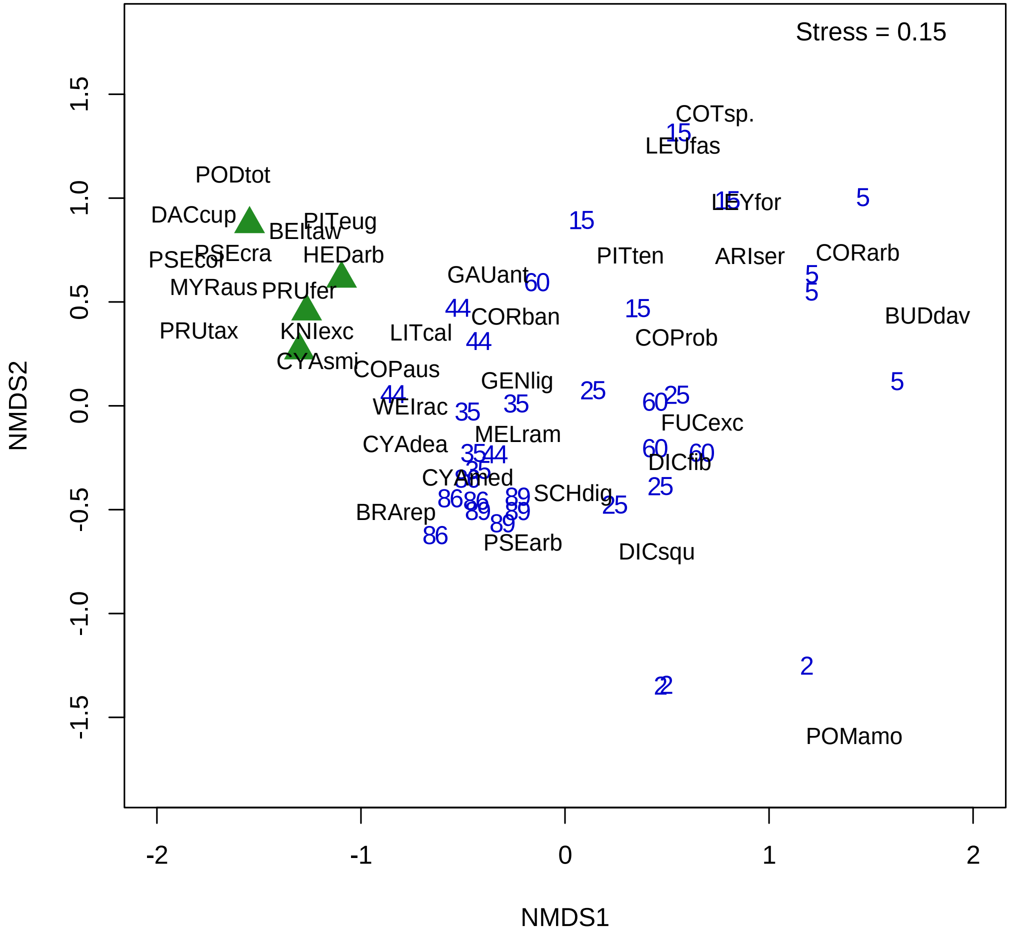
In addition to stand structure, proximity to seed sources are important



Predicted indigenous woody species richness (*S*) as a function of stand age and meso-scale topographic exposure, across a chronosequence of nine *Pinus radiata* plantation stands aged 2–89 years, Kinleith Forest, central North Island, New Zealand. For comparative purposes, the *S* from an old-growth natural forest ("NF") reference site is shown. Error bars = ±1SE; dashed lines indicate the 95% CI.

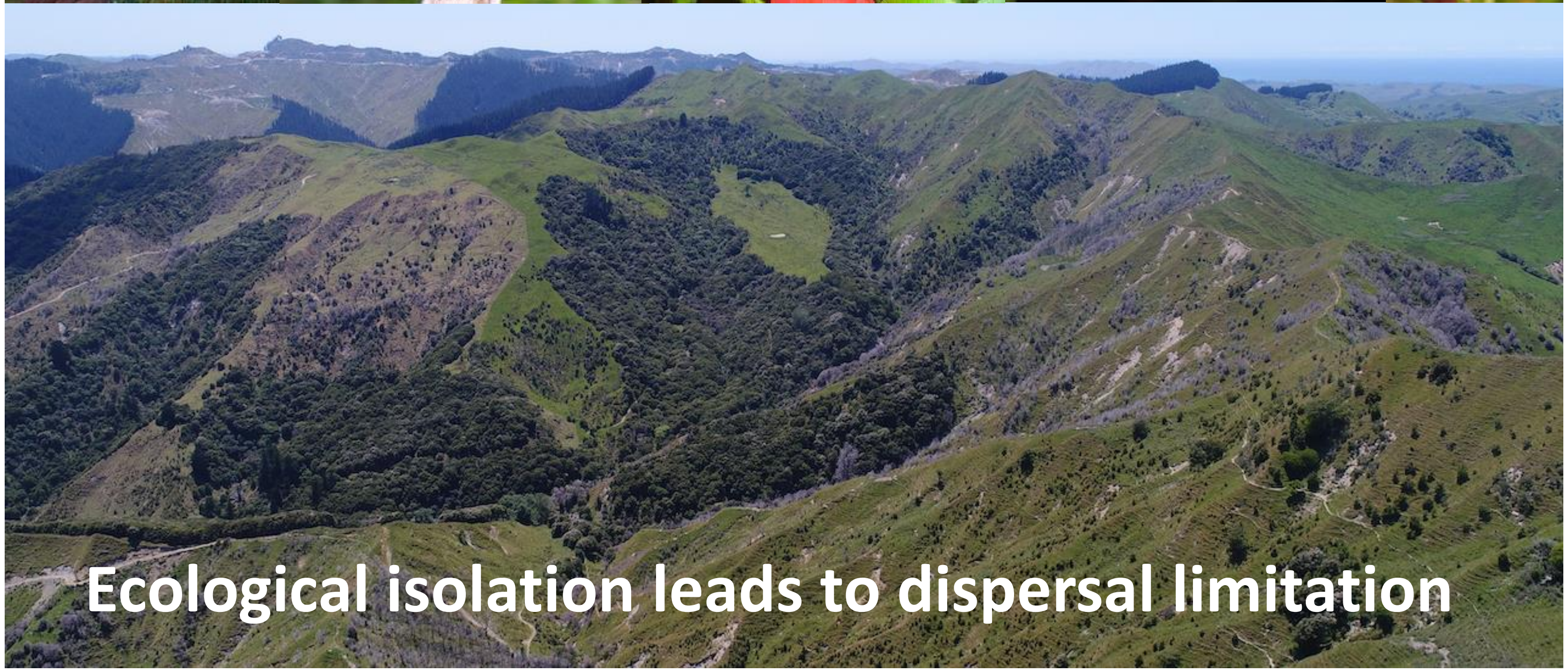
Both stand age and native forest proximity important for understorey regeneration

Forbes et al. 2019. *NEW ZEAL J FOR SCI*



Nonmetric dimensional scaling (nMDS) ordination of species composition across chronosequence of nine *Pinus* plantation stands aged 2–89 years, Kinleith Forest, central North Island, New Zealand. The composition of an old-growth natural forest reference site is also included, shown by triangles.

Factors Influencing Regeneration – Seed Dispersal



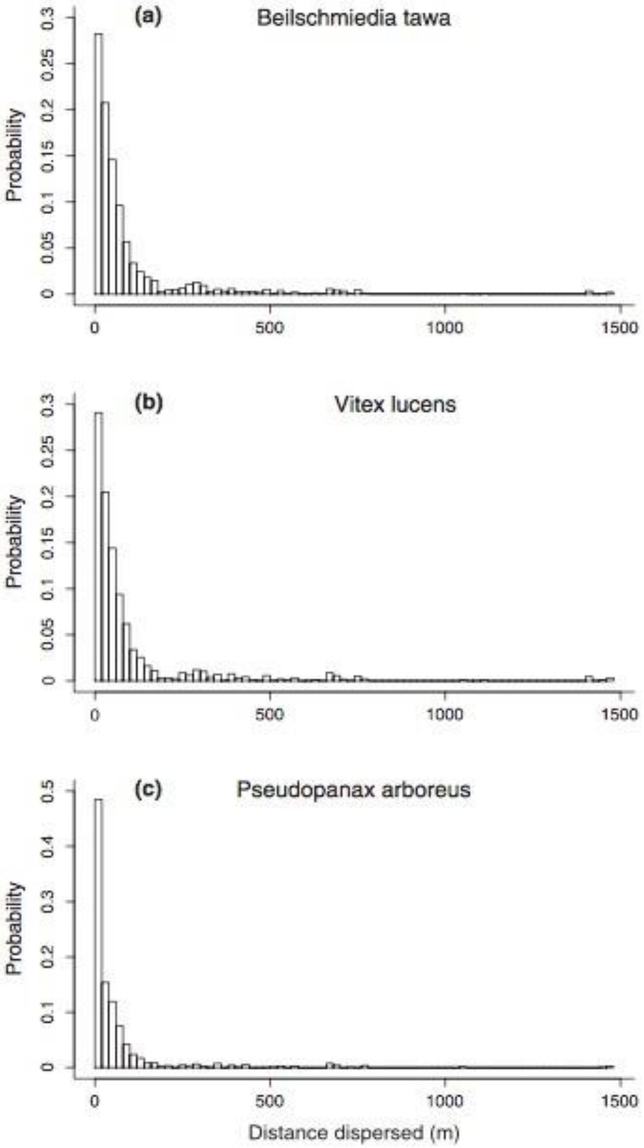


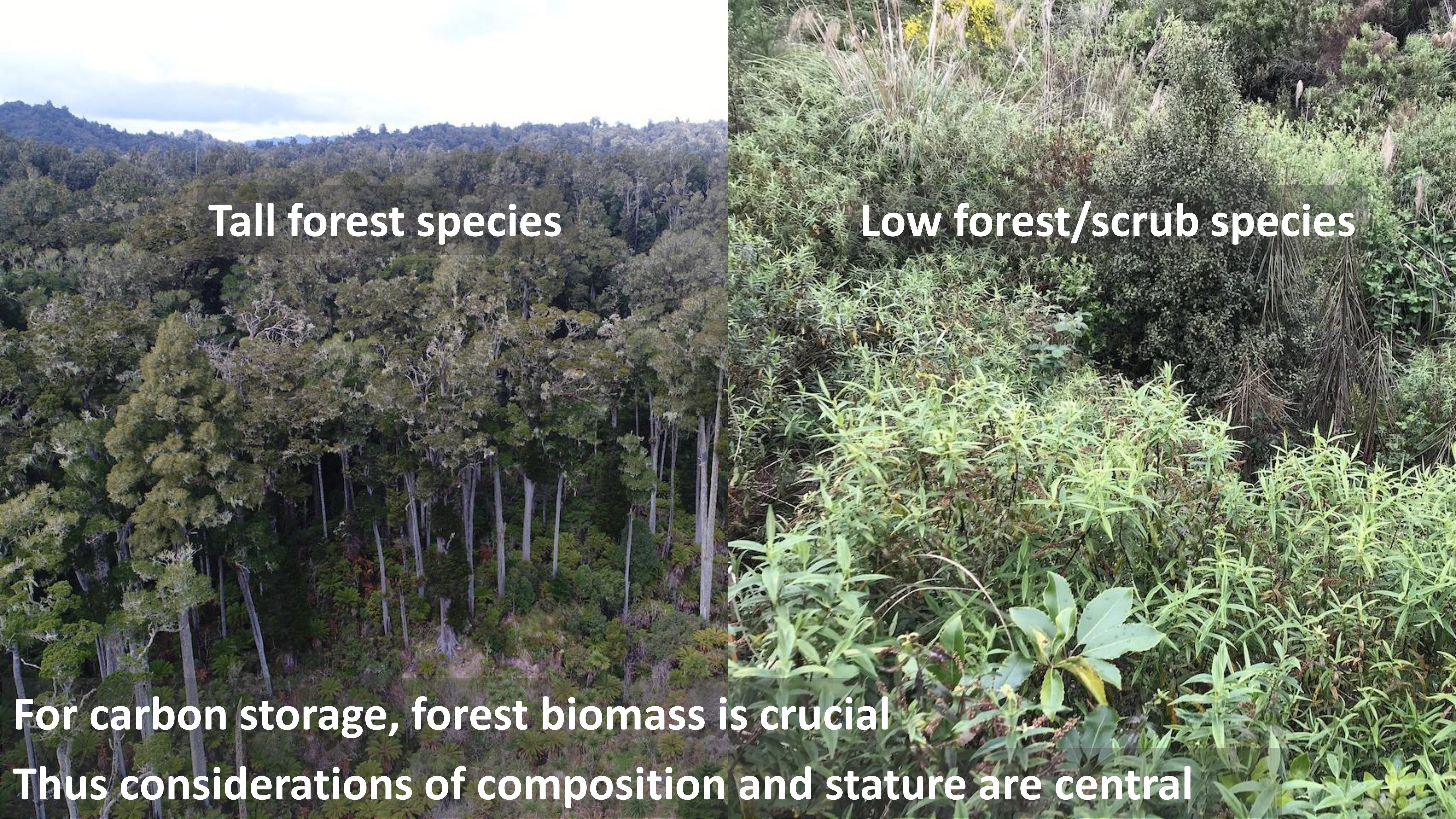
Figure 1 Estimated probability distributions of *Hemiphaga novaeseelandiae* seed dispersal distances at 20 m intervals for (a) *Beilschmiedia tawa*, (b) *Vitex lucens*, and (c) *Pseudopanax arboreus*. Dispersal distances were generated using a mechanistic model that incorporated empirical data for individual *H. novaeseelandiae* movements and seed retention times. Note differences in the *y*-axis scales.

Only 79–88% of seeds were dispersed > 100 m, and only < 1% of seeds were dispersed > 1,000 m

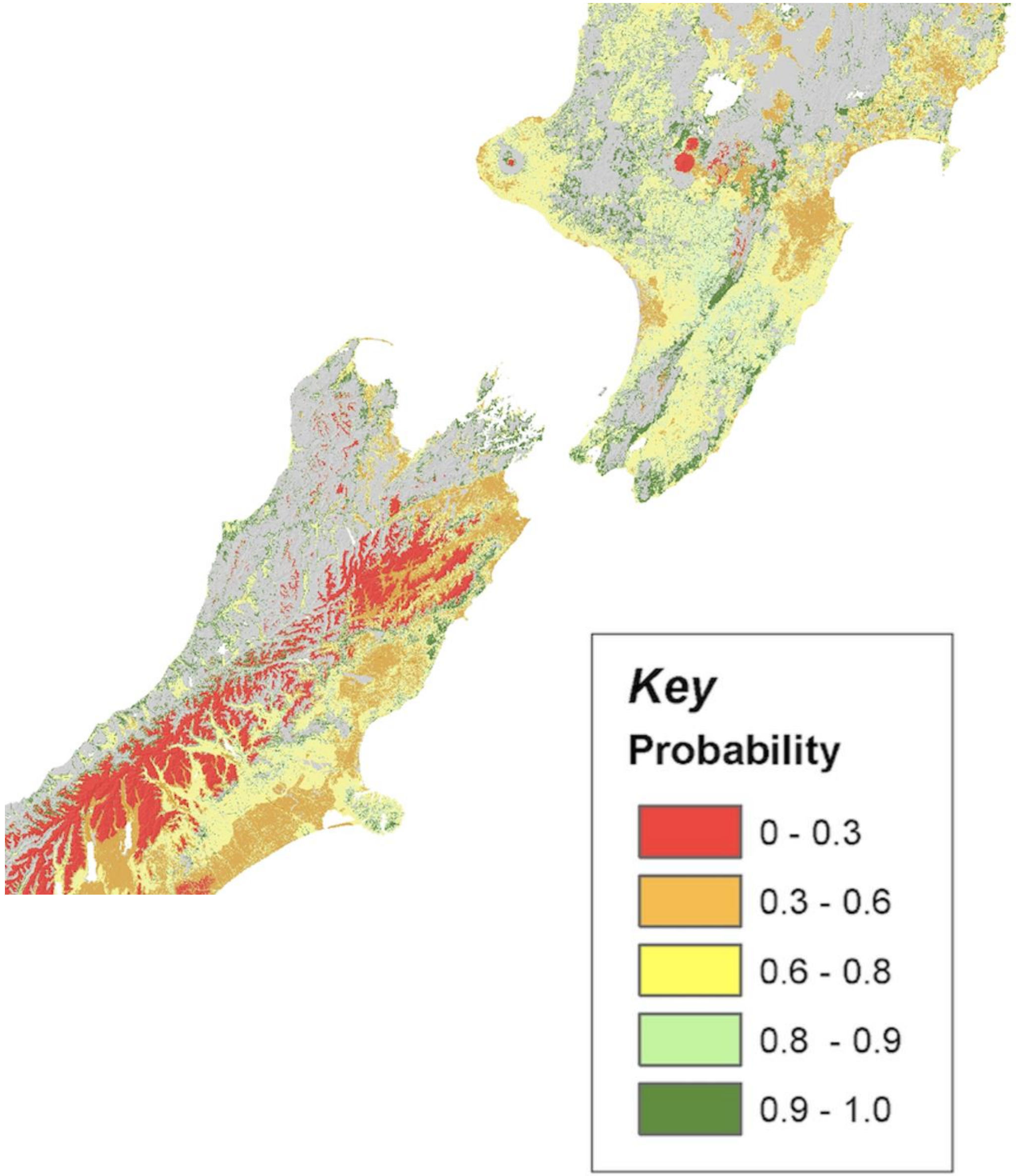
Wotton & Kelly 2012 *J Biogeography*

Seed source amount versus distance?

Fahrig 2013. J BIOGEOGR


Tall forest species
Low forest/scrub species
For carbon storage, forest biomass is crucial
Thus considerations of composition and stature are central

Factors Driving Natural Afforestation



Variable	Contribution (%)
Mean annual temperature	**44.9**
% woody cover within 25 m	34.1
Mean annual rainfall	**5.0**
Mean annual solar radiation	3.9
Minimum annual temperature	3.5
Distance to forest	2.5
October soil water deficit	2.3
Mean October wind speed	2.2

Predicted tree occurrence probability in non-forest vegetation in New Zealand

Mason et al. 2013. *PLOS ONE*

Factors Influencing Regeneration – Herbivore Browse

Diet preferences of introduced ungulates[1]

Ungulate Preference Class		
Preferred	**Not Selected**	**Avoided[2]**
Wineberry	Marbleleaf	Tawa
Cabbage tree	Hinau	Rimu
Tree fuchsia	Pigeonwood	Beech spp.
Broadleaf	Sth. Is. kowhai	Halls & true totara
Mahoe		Miro
Five finger		Matai
Lancewood		

[1] Forsyth et al. 2002 *NEW ZEAL J ZOOL*

[2] This means consumption is less than expected, based on availability

Summary:
Key considerations for permanent carbon forestry using a radiata pine nurse

- Stand age
- Canopy and understorey structure
- Seed source proximity (distance or amount)
- Climate
- Herbivore species and numbers


Optimising Pines for Permanent Carbon Forestry

Key Ecological Objectives

To achieve:

- A high biomass
- An acceptable carbon profile through the transition
- A self-sustaining permanent forest

With the minimum necessary level of intervention

Managing a Transition

- Reliance on natural processes:
  - Canopy shade
  - Propagule dispersal
  - Disturbance-driven regeneration
- Key management actions:
  - Addressing canopy and understorey competition
  - Adequate propagule sources
  - Herbivore management

Permanent Forest Design Criteria (Working Concept)

Site suitability	Level of Feasibility/Intervention		
	Feasibility		
	Low	Moderate	High
Climate (mean annual temperature and rainfall)			
	Interventions		
	Low	Moderate	High
Stand age, canopy and understorey structure			
Seed source proximity (distance or amount)			
Herbivore spp. and numbers			

Currently determining category boundaries and evidence basis

Further Research; What We Still Need to Know

- Further work on the transition
    - Guidance for canopy interventions to aid a transition
        - Canopy regime to transition, methods of gap creation, staging, maintenance – across rainfall and temperature gradients
    - Seed source proximity – distance versus amount and corresponding guidance over levels of propagule introduction
    - Landscape-scale herbivore management or fencing technologies
- Evidence-based policy for permanent forestry using this approach – soil, biodiversity and/or carbon applications

Acknowledgements and Contact Details

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