

# USING BIG DATA TO PREDICT RESTORATION POTENTIAL

Andrew R. Marshall,  
Marion Pfeifer, et al.

# Talk Overview

FoRCE

- (1) Lianas vs. trees
- (2) Restoration planning

[pilots, methods, and intentions]

# Why Restore?

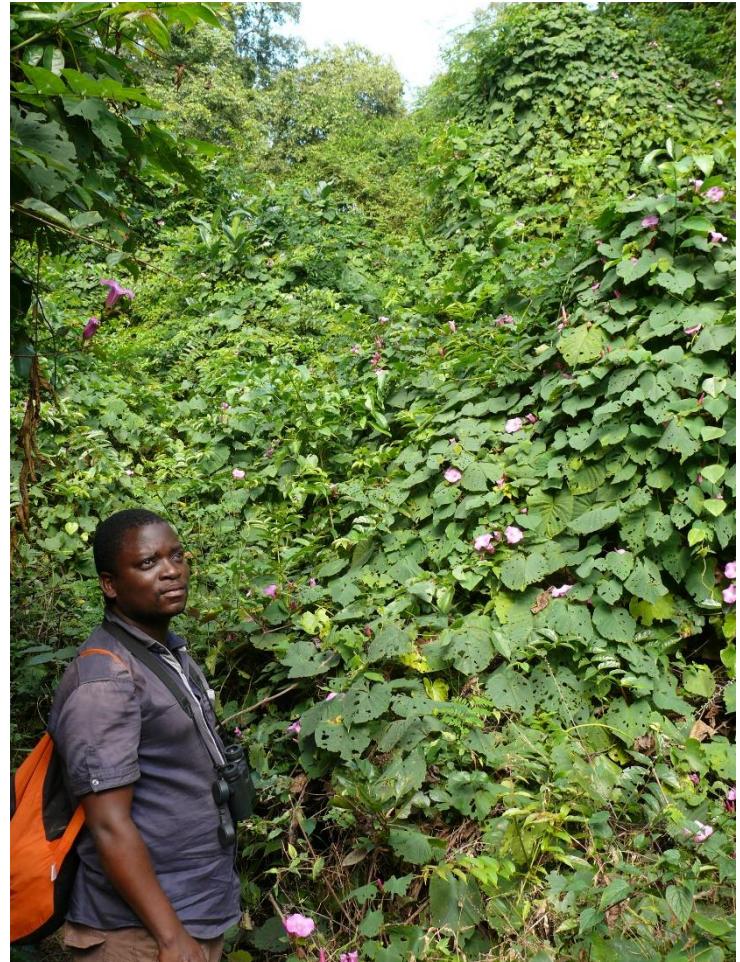
“One of the greatest challenges for ecologists this century” (Duncan & Chapman 2003)

## Forest Restoration

- TFs: Half lost; One third degraded
- 1 Trillion Trees Campaign
- Bonn Challenge: 350 Mha by 2030

### (1) Lianas vs. trees

- Threatening global C sink?
- Neotropics:
  - Liana:tree biomass  $\uparrow$  4.6%/yr
  - Tree cover  $\uparrow$  50-80%/yr
  - Net carbon uptake  $\downarrow$  76%/yr
- But lianas have value
- Big data needed...



*Uncaria africana*  
(Rubiaceae)



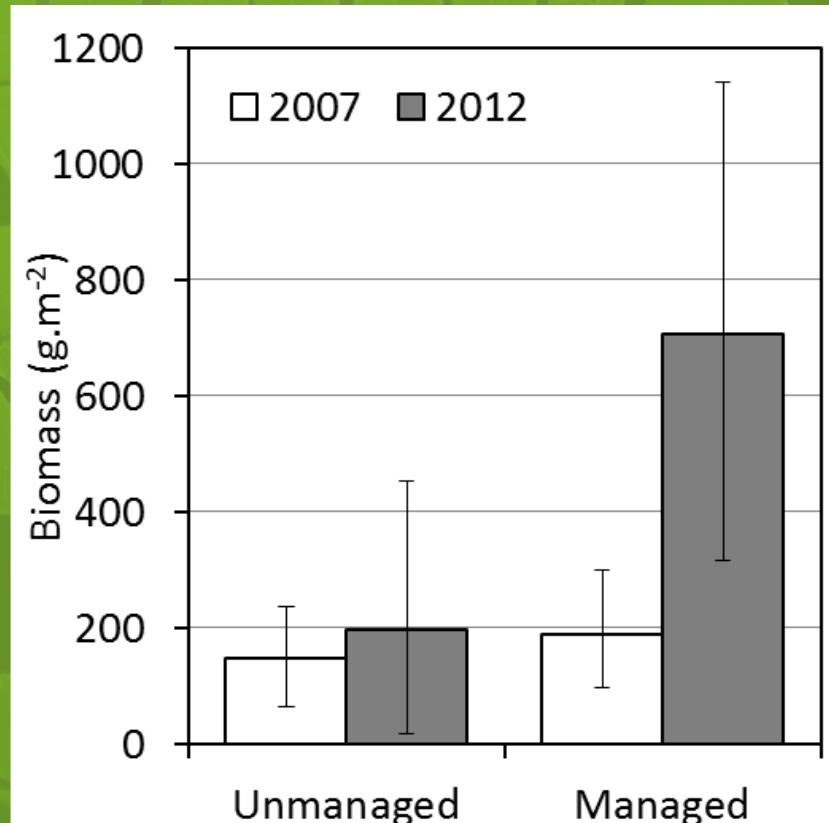
Marshall et al 2017 *Afr J Ecol*

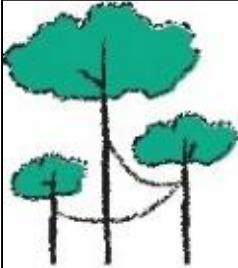
## Cutting Pilot

- Cutting → ↑ biomass
- Growth ↓ all size classes
- Net biomass ↑ 6× faster rate

## Pantropical Review

- Impact ~equivalent across tropics
- Bias: elevation; Neotropics; two pathways? ...





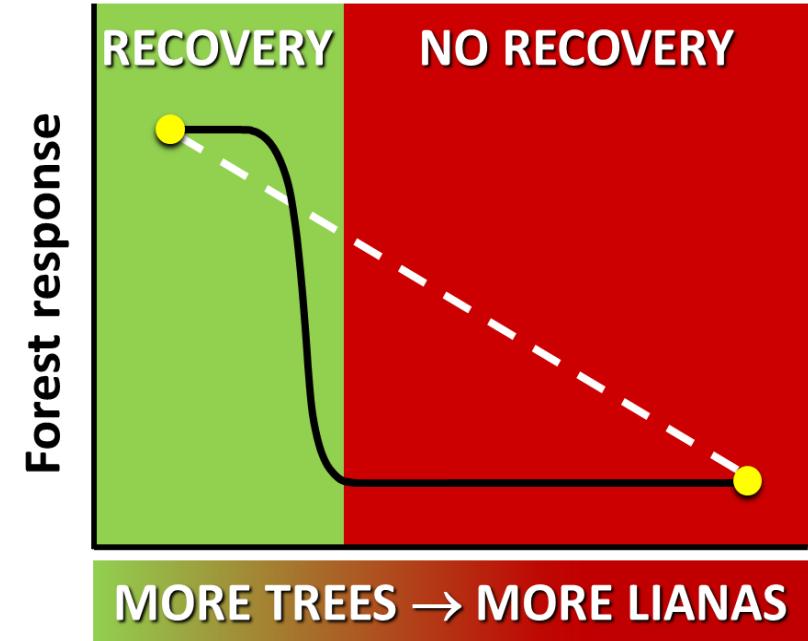
# Forest Restoration & Climate Experiment

- UY Priming → ARC (& RT/WLT)
- Africa → Australia → upscaling
- Lianas vs. recovery & climate
- Plots / photos / satellite
- Cut **some** lianas



Australian Government

Australian Research Council



## SO WHAT?

- Extent of impact?
- Threshold response / drivers?
- Can we minimise liana cutting?

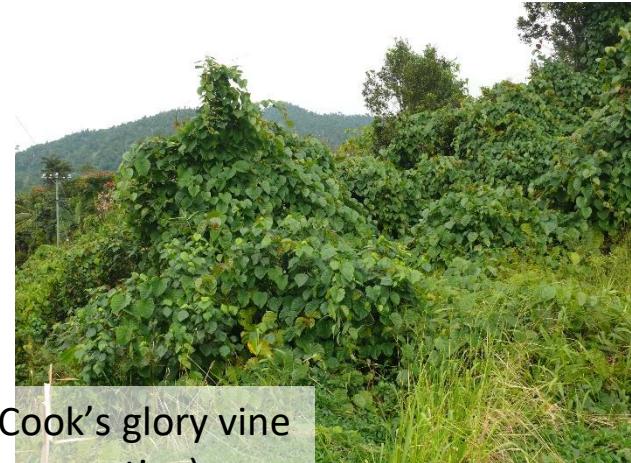


# Australian Lianas

## (should we cut?)

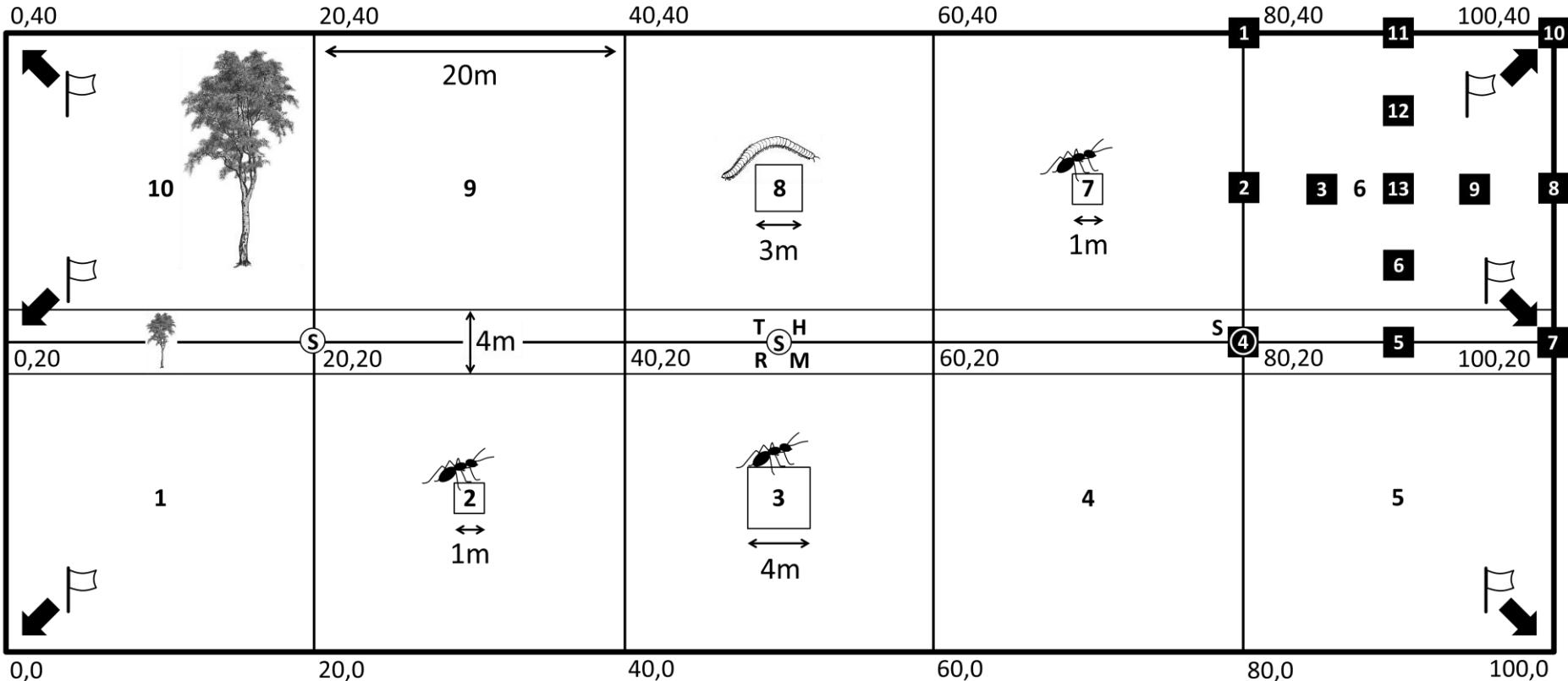


*Merremia peltata*, Cook's glory vine  
(Convolvulaceae, native)



Cat's claw creeper (exotic)

# FoRCE Plot (0.4ha)



- **Stratification:** (a) climate; (b) degradation
- **Management:** Liana cutting; BACI design
- **SEEKING:** (a) PhDs / postdoc; (b) Collaborators; (c) Asian / Tropical American Sites

# (2) FoRCE: Science → Practice



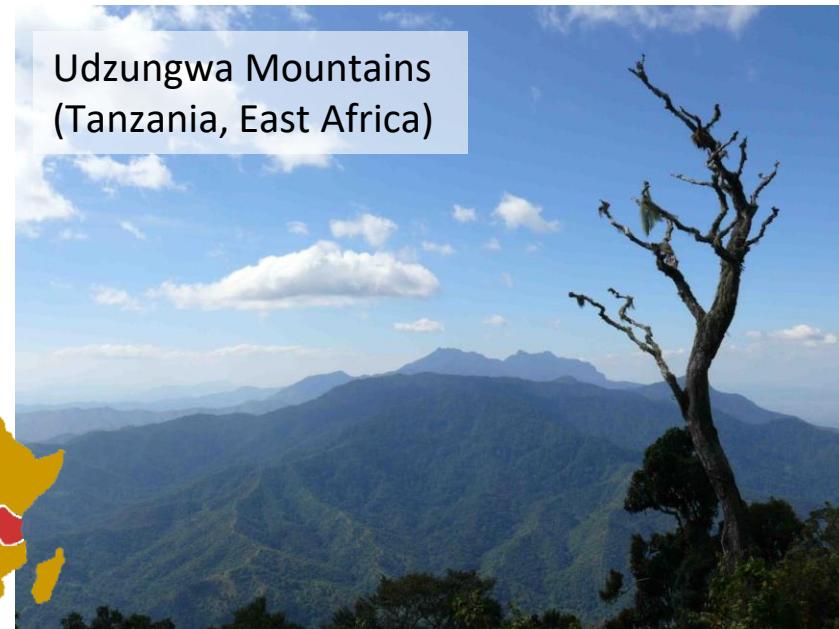
## Restoration Planning:

- Seed germination/  
planting
- Restoration planning



# Landscape Restoration Planning

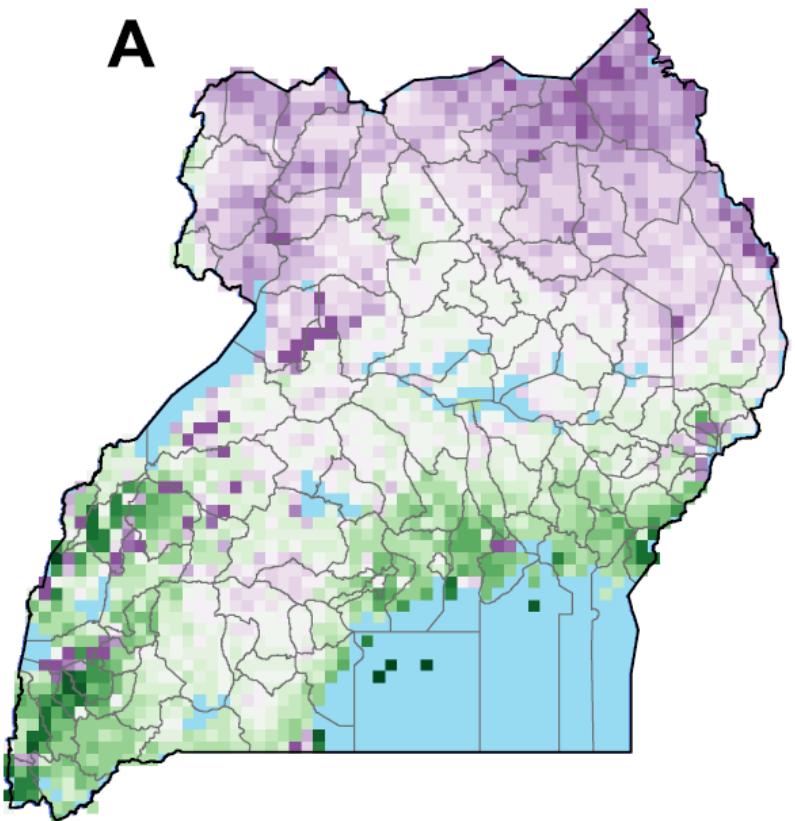
Govts & donors need  
to set priorities...



## Our Approach

- (1) Plot data (9 projects)
  - (2) Estimate biomass & deficit
  - (3) Method → cost → cost-effectiveness
- **RESTORATION POTENTIAL**

# Cost Effectiveness → Restoration potential



UGANDA

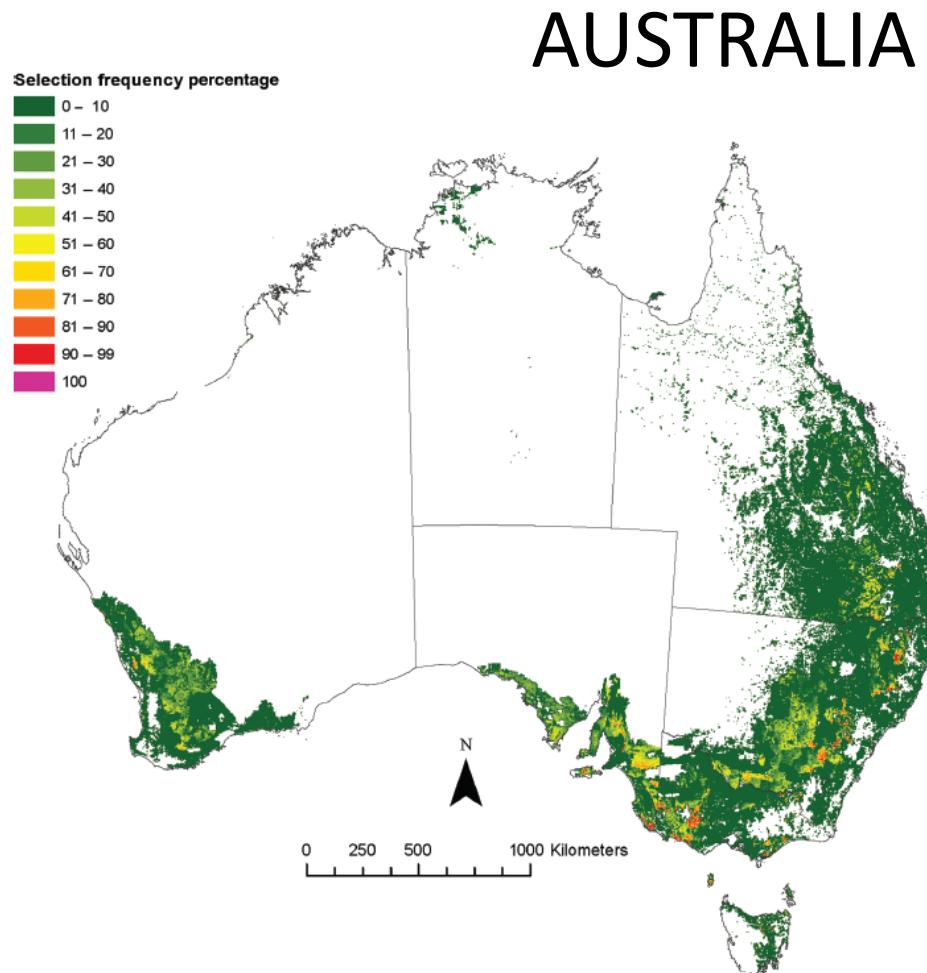
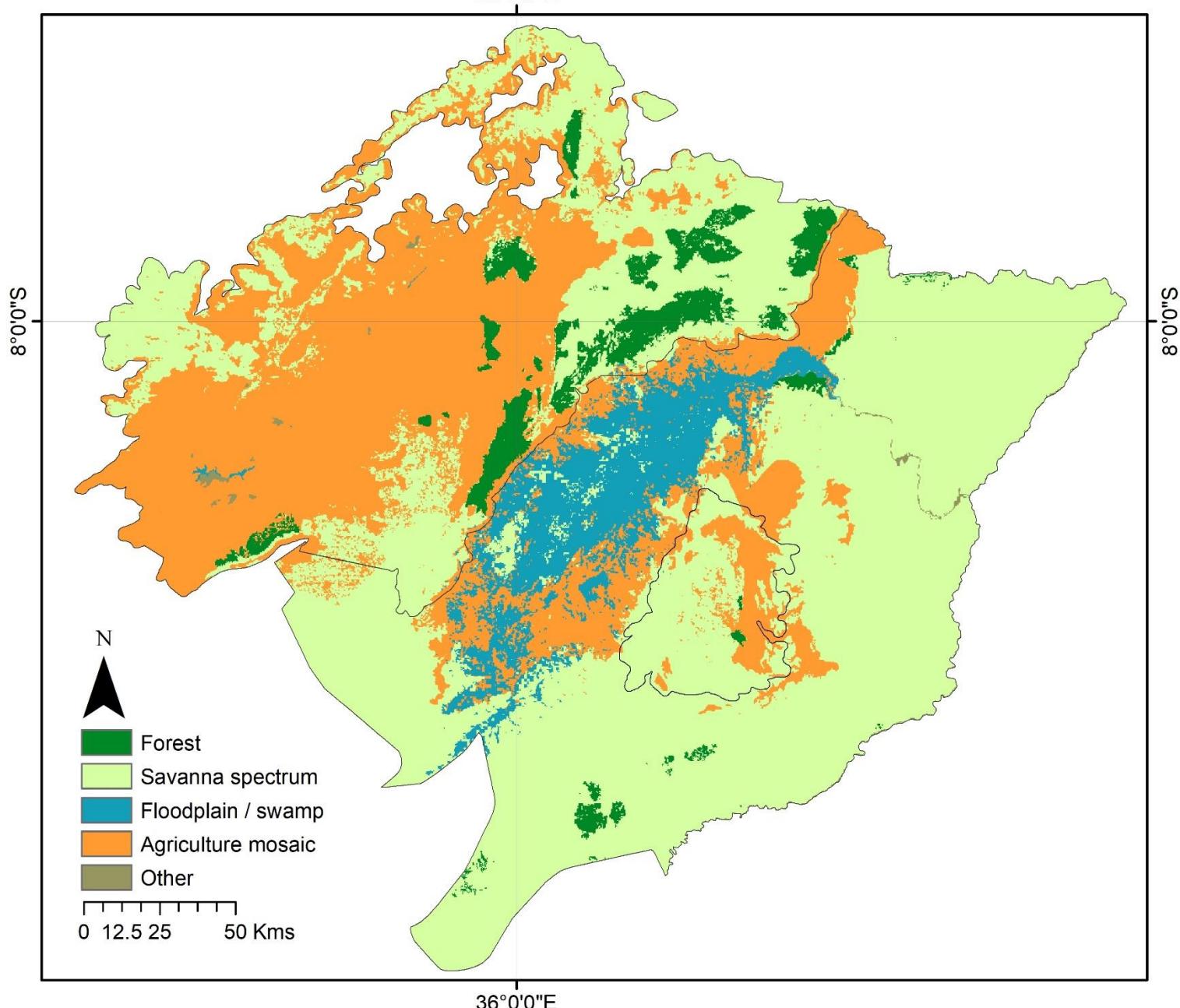
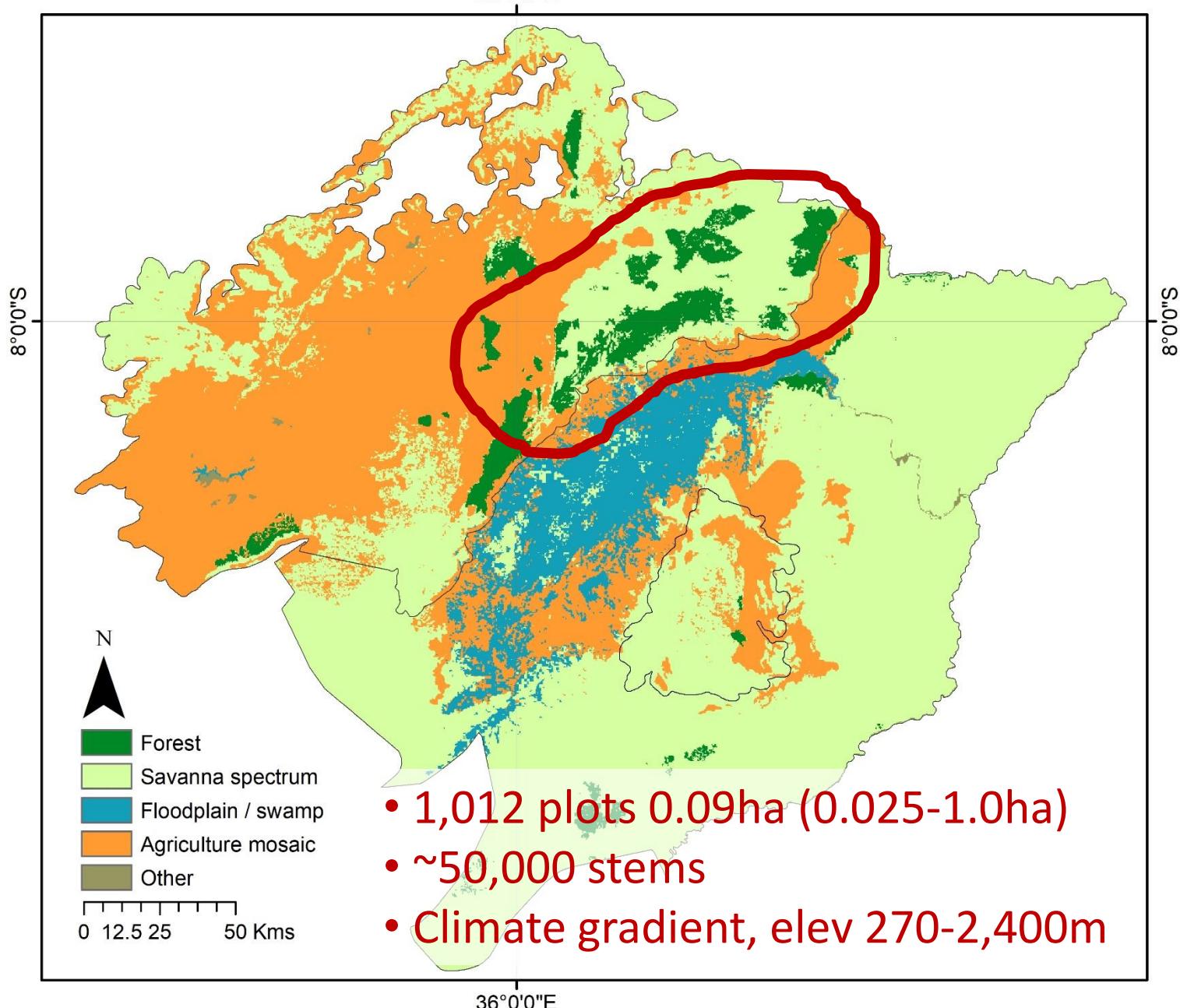


Figure 4. (a) Relative priority for reforestation to meet 30% vegetation restoration targets across Australia, assuming a carbon market as per scenario 11 (priority set 2).

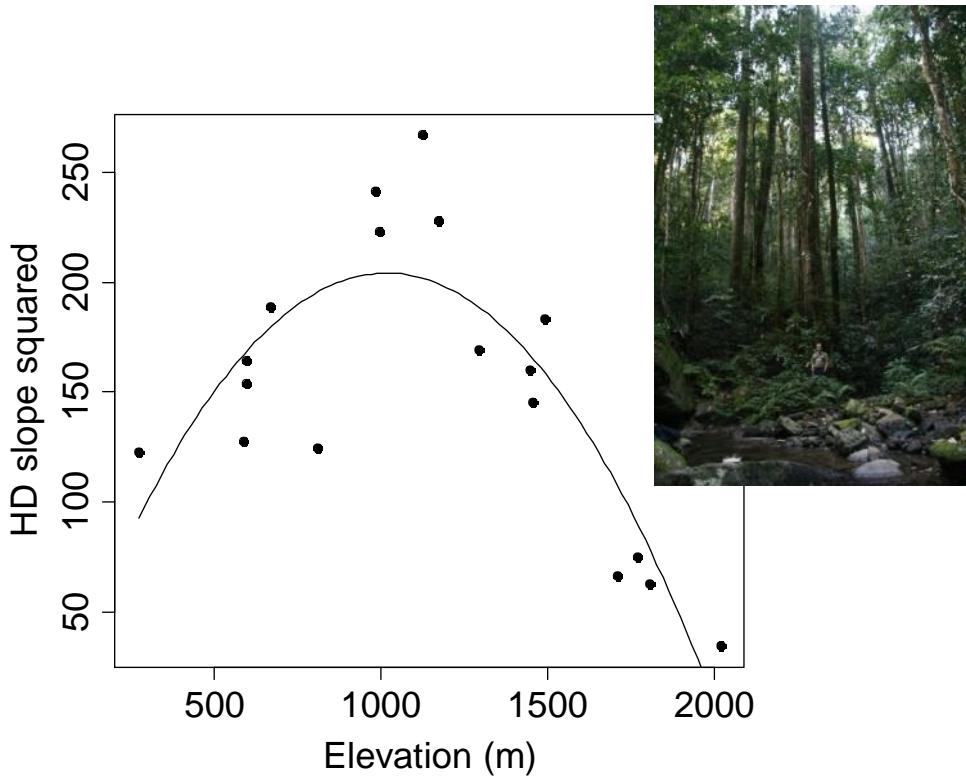


Step 1: Veg plots → Biomass → Biomass deficit



Step 1: Veg plots → Biomass → Biomass deficit

# AGB / AGC



- AGC: elevation/PET; elephants; slope
- Tree shape varies with elevation
- $\text{Dbh} > \text{height} >> \text{species}$

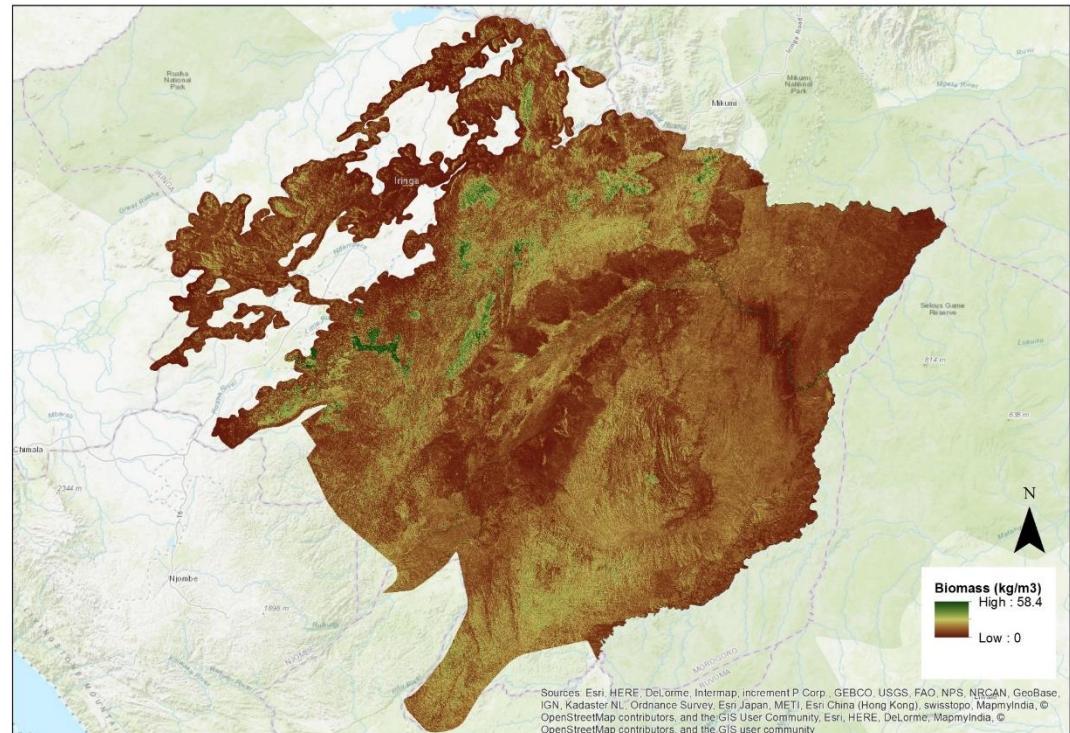
- Carbon estimate using height:  $174.6 \pm 32.2 \text{ t ha}^{-1}$
  - Carbon estimate using diameter alone:  $229.6 \pm 37.0 \text{ t ha}^{-1}$
- **50t ha<sup>-1</sup> overestimate !!**

# Biomass calculation

- Diameter (all stems)
  - Height (~10%; d:h models)
  - Wood density (~40%; open vs. closed canopy)
- Three allometric equations

## Spectral upscaling

- Recent plots only
- Rapideye 5m → 20m pixel
- Beta logistic regression



Step 2: Veg plots → Biomass → Biomass deficit

# Maximum biomass

- Estimate of former biomass (e.g. Gourevitch et al 2016)
- Closed canopy plot biomass (min plot size 0.1ha)
- Biomass-climate [76.2%D]: MWD (-); elevation ( $\cap$ ); slope (-); seasonality (+); temp range (-)
- Upscaling 100m

# Biomass deficit

- Maximum biomass MINUS current biomass
- Basic restoration potential



Step 2: Veg plots → Biomass → Biomass deficit

# Step 3: Restoration Potential

i.e. Likely biomass gain (and carbon sequestration) that could be achieved and its variability and cost-effectiveness across the region and landcover classes...

$$AGC\$_i = (\Delta AGC_i * p) / \$_i$$

AGC\$ = Carbon sequestration per US\$ (kg.US\$<sup>-1</sup>)

$\Delta AGC$  = expected change in carbon

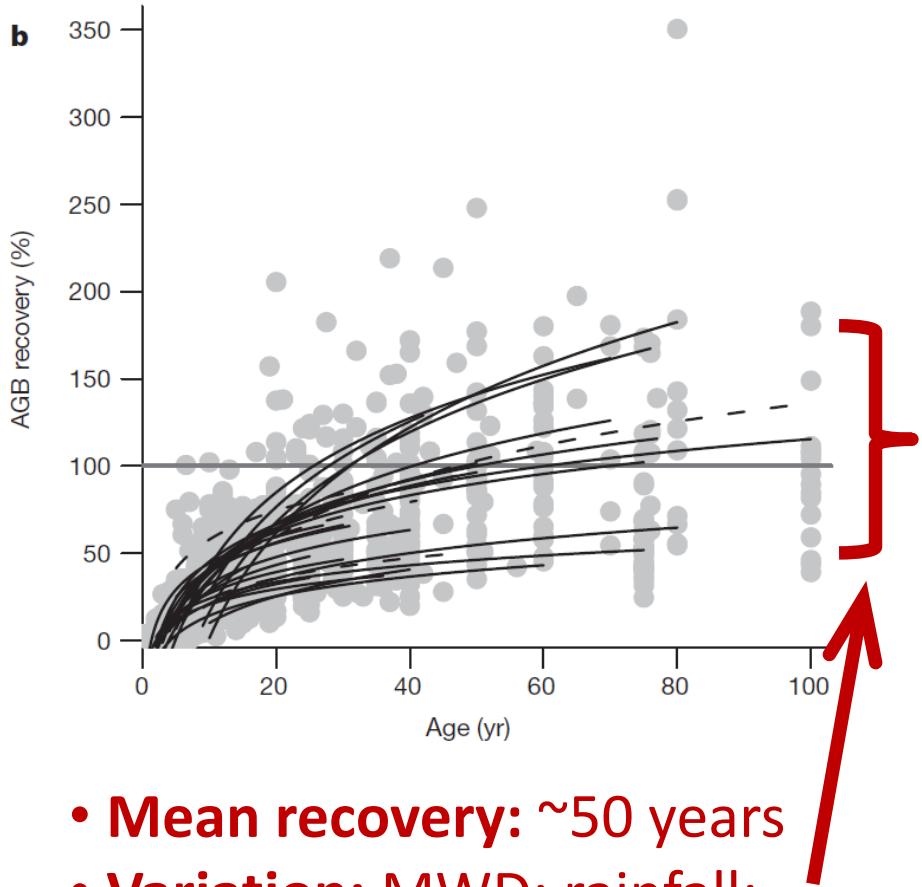
p = expected probability of success \$ = expected cost in US\$

5-year and 50-year scenarios

# Components of Cost-effectiveness:

## 1. Expected change in AGC

- Biomass deficit
- Pattern of biomass recovery estimated  
(Poorter et al 2016 Nature)
- $AGC = AGB \div 2$
- Intervention needed where biomass loss >70-80% (Hanski 2011 Ambio)...



- **Mean recovery:** ~50 years
- **Variation:** MWD; rainfall; seasonality (Poorter et al 2016)

# **Components of Cost-effectiveness:**

## **2. Probability of Success**

**Scenarios:** Pessimistic (25%), Realistic (50%)  
and Optimistic (75%) [donors]

*Range elsewhere: 20-96%, Felix Finkbeiner, pers. comm.*

**UNKNOWN:** Variation between methods?  
Assume biomass gain quicker for planting in  
first 5 years, but biomass equal after 50 years  
(Shoo et al. 2016)

# Components of Cost-eff: 3. Cost per ha

Which method?

Landcover class	Landcover feature	Restoration method								
		No action	Vine cutting	Herb/shrub cutting *	Exotic tree removal	Firebreak cutting	Grass cutting **	Enrichment planting	Framework planting	Nurse trees & soil ***
PESSIMISTIC SCENARIO										
Forest	Biomass	≥30	<30	<30	-	-	-	<30	0	-
	Elevation	Any	<1,000	≥1,000	-	-	-	Any	Any	-
Savanna	Biomass	-	-	-	-	Any	<30	<30	≥5 and <10	0
	Distance	-	-	-	-	Any	Any	Any	Any	Any
Agriculture mosaic	Biomass	-	-	-	Any	<30	<30	<30	≥5 and <10	0
	Distance	-	-	-	Any	Any	Any	Any	Any	Any
REALISTIC SCENARIO										
Forest	Biomass	≥25	<25	<25	-	-	-	-	-	-
	Elevation	Any	<1,000	≥1,000	-	-	-	-	-	-
Savanna	Biomass	-	-	-	-	Any	<25	<1	≥1 and <5	0
	Distance	-	-	-	-	Any	Any	≥50	≥50	0
Agriculture mosaic	Biomass	-	-	-	<25	Any	<25	<1	≥1 and <5	0
	Distance	-	-	-	Any	Any	Any	≥50	≥50	0
OPTIMISTIC SCENARIO										
Forest	Biomass	≥20	<20	<20	-	-	-	-	-	-
	Elevation	Any	<1,000	≥1,000	-	-	-	-	-	-
Savanna	Biomass	-	-	-	-	<20	<20	0	<1	0
	Distance	-	-	-	-	Any	Any	0	≥100	0
Agriculture mosaic	Biomass	-	-	-	-	<20	<20	0	<1	0
	Distance	-	-	-	-	Any	Any	0	≥100	0

# Components of CE: 3. Cost per ha

- Land purchase
- Community engagement (agriculture)
- Community engagement (50% <3km)
- Seeds/nurseries
- Equipment
- Labour
- Transport per distance
- Management
- Admin
- Security

# Example Cost Calculations

(PENDING FE PAPER ☺)



## Vine cutting

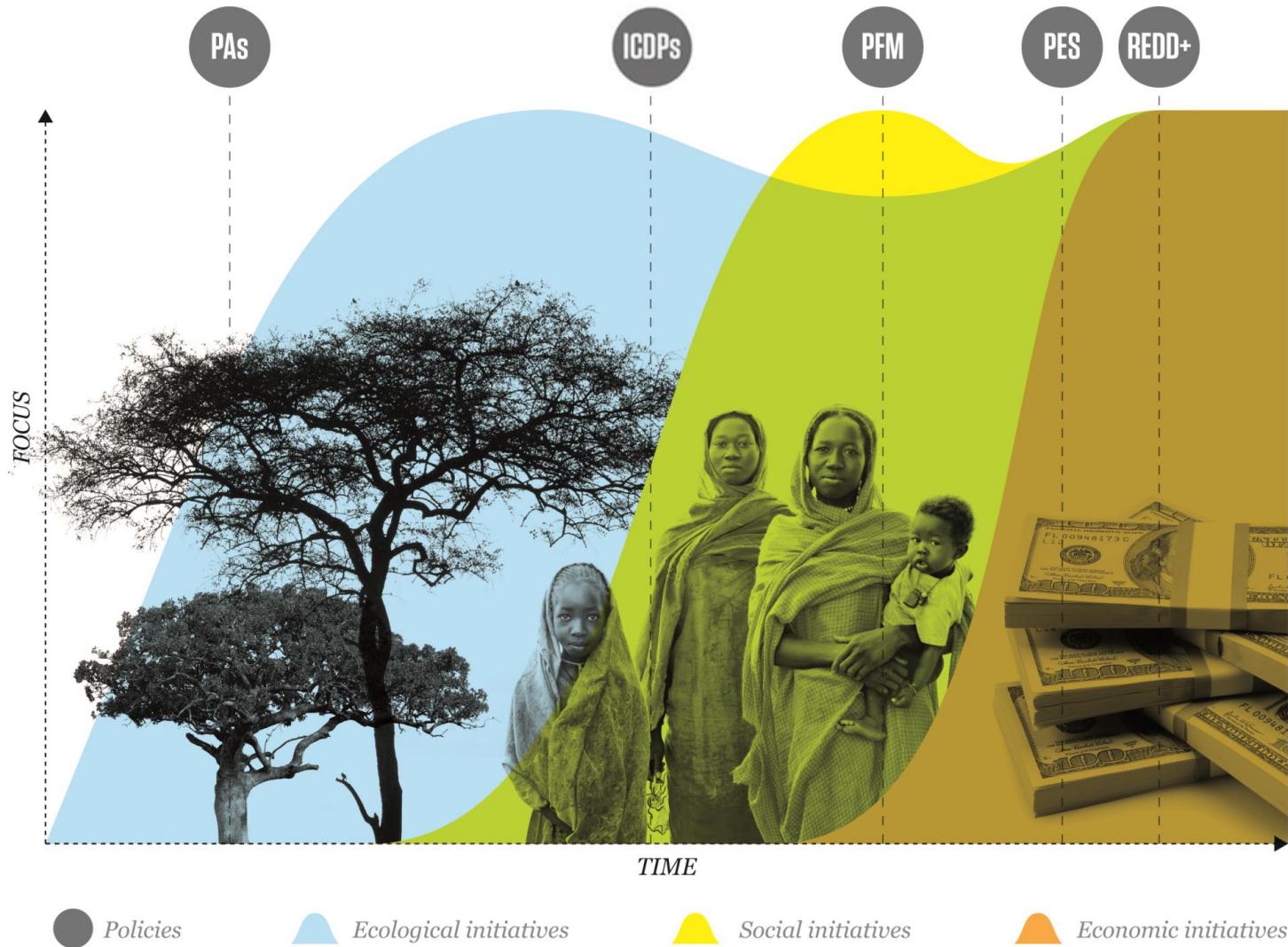
- Tanzania: US\$5.45/ha/year (Marshall et al 2017) [no admin]
- West Africa: US\$1-4/ha (Bongers et al 2002) [no admin?]
- Bolivia & Brazil: \$11/ha (range \$1–16; various) [no admin?]
- Reforest Africa: US\$69.47/ha/yr → US\$347.35/5 yr

## Tree planting

- 44x more expensive (Marshall et al 2017) [no admin]
- Uganda: US\$1200/ha/5yr (Omeja et al 2009) [admin costs?]
- Reforest Afr: US\$1,297.64 (**£1/tree**) then \$69.47/yr  
→ US\$1,644.99/5 yr → 4.7x more expensive
- Plant for the Planet €1/tree; others US\$1-2/tree (US\$0.30 – \$50)
- Australia: \$30,000 vs \$5,000 [\$0-\$10,000] (weed control)  
→ 6x more expensive (Catterall & Kanowski 2010)

# Waves of Evolution in African Forest Conservation

Latham 2014 PhD  
(and in prep)



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**Thanks:** Field assistants, TAWIRI, COSTECH – tunashukuru sana wote!

A wide-angle photograph of a dense mountain range. The foreground is filled with the dark green canopy of tropical trees, including several palm trees. In the middle ground, a massive, steep mountain rises, its slopes covered in a thick, vibrant green forest. The background shows more mountain peaks fading into a light blue haze under a clear, pale blue sky.

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