Sequestering carbon in regeneration:
An elaborate hoax or landholders making a difference?

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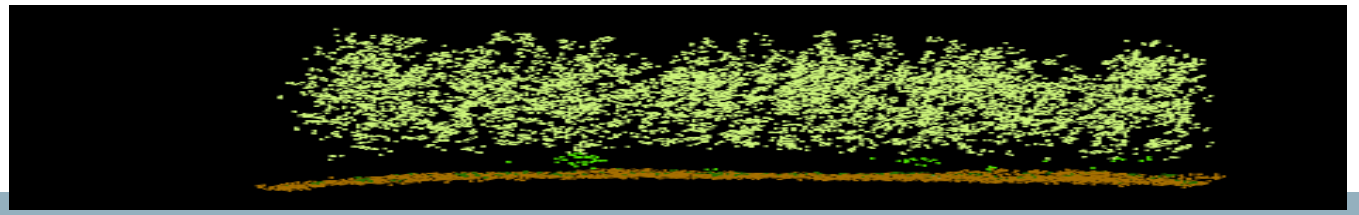
Human Induced Regeneration: to generate forests and greater carbon density

Lecturer in charge of toys



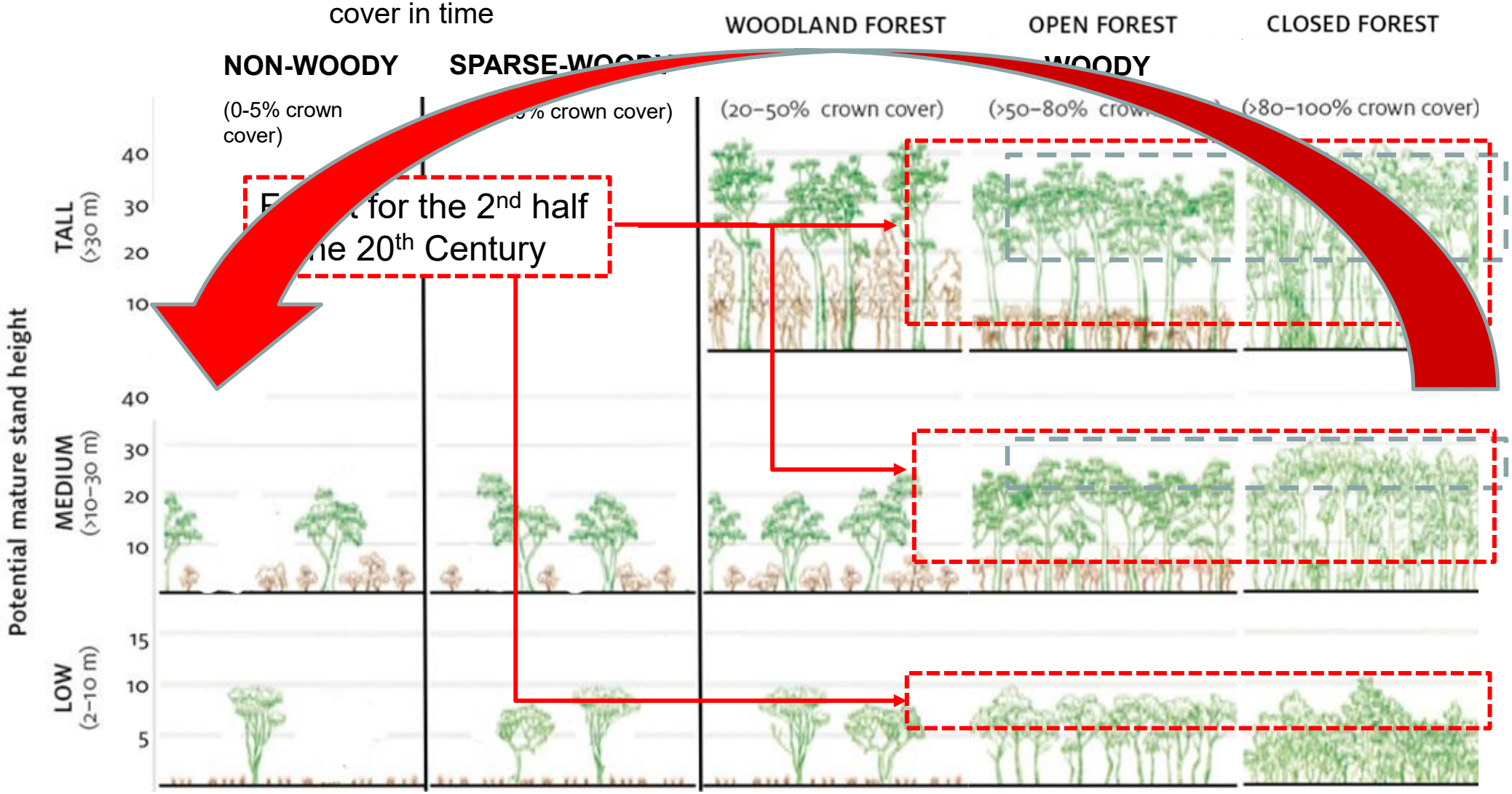
Professor of Error

- All models are wrong…
  - some are useful…
  - in the right context
- All measurements are a compromise of:
  - Resources/time/money
  - Available tools/technology
  - Questions needing answers/decision points
  - Object itself

Object: What was/is/will be “forest”

May be classified as Forest if sufficient plants to exceed 20% crown cover in time

Classified as Forest (if at least 0.2 ha)



Forest for the 2nd half of the 20th Century

Forest up until 1st half of 20th Century

Decisions: HIR

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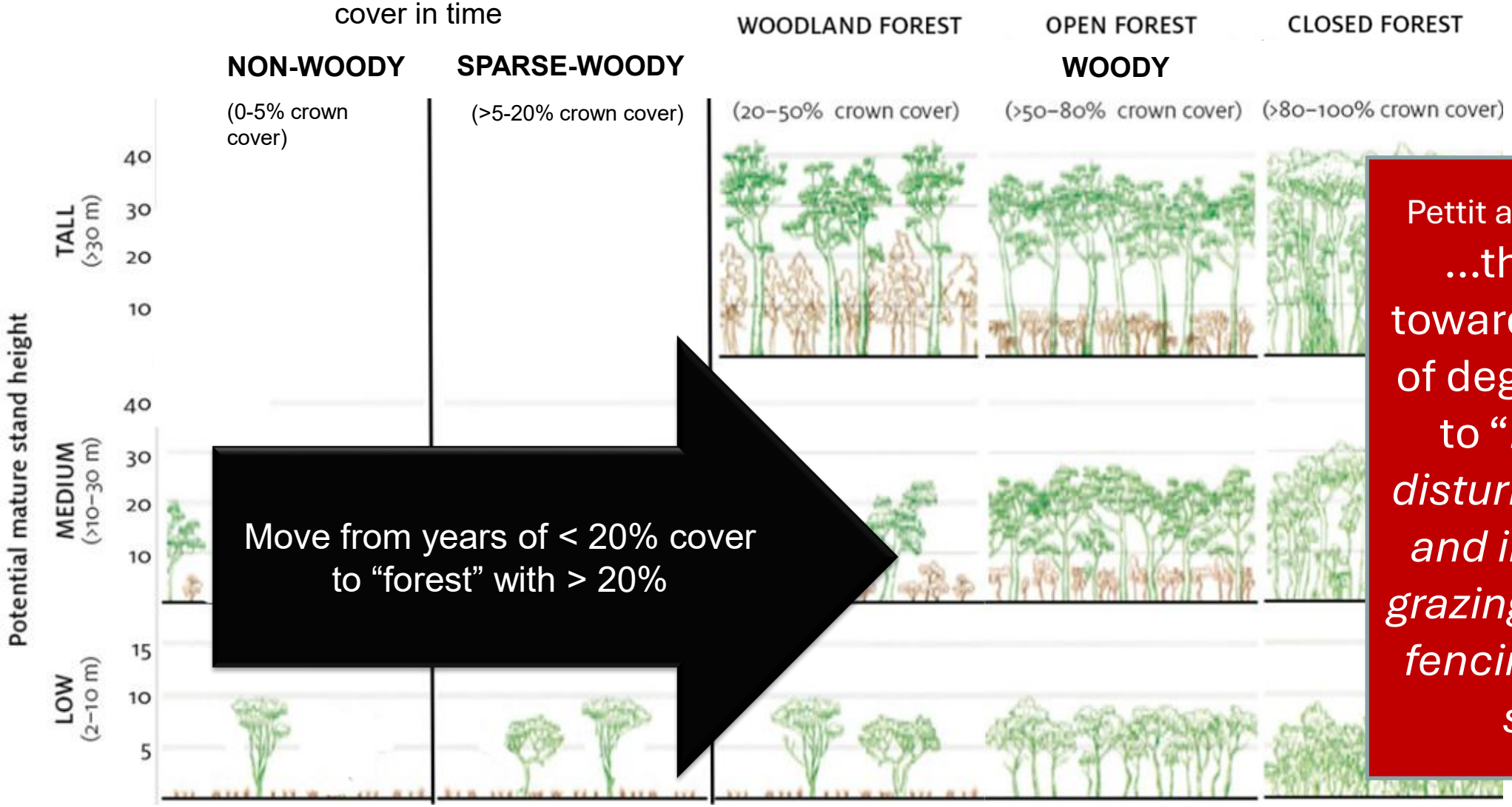

Move from years of < 20% cover to "forest" with > 20%

Pettit and Froend (2000)

...the first step towards restoration of degraded land is to "*remove the disturbing element, and in the case of grazing this requires fencing to exclude stock...*"

Criticism #1: no “permanence”

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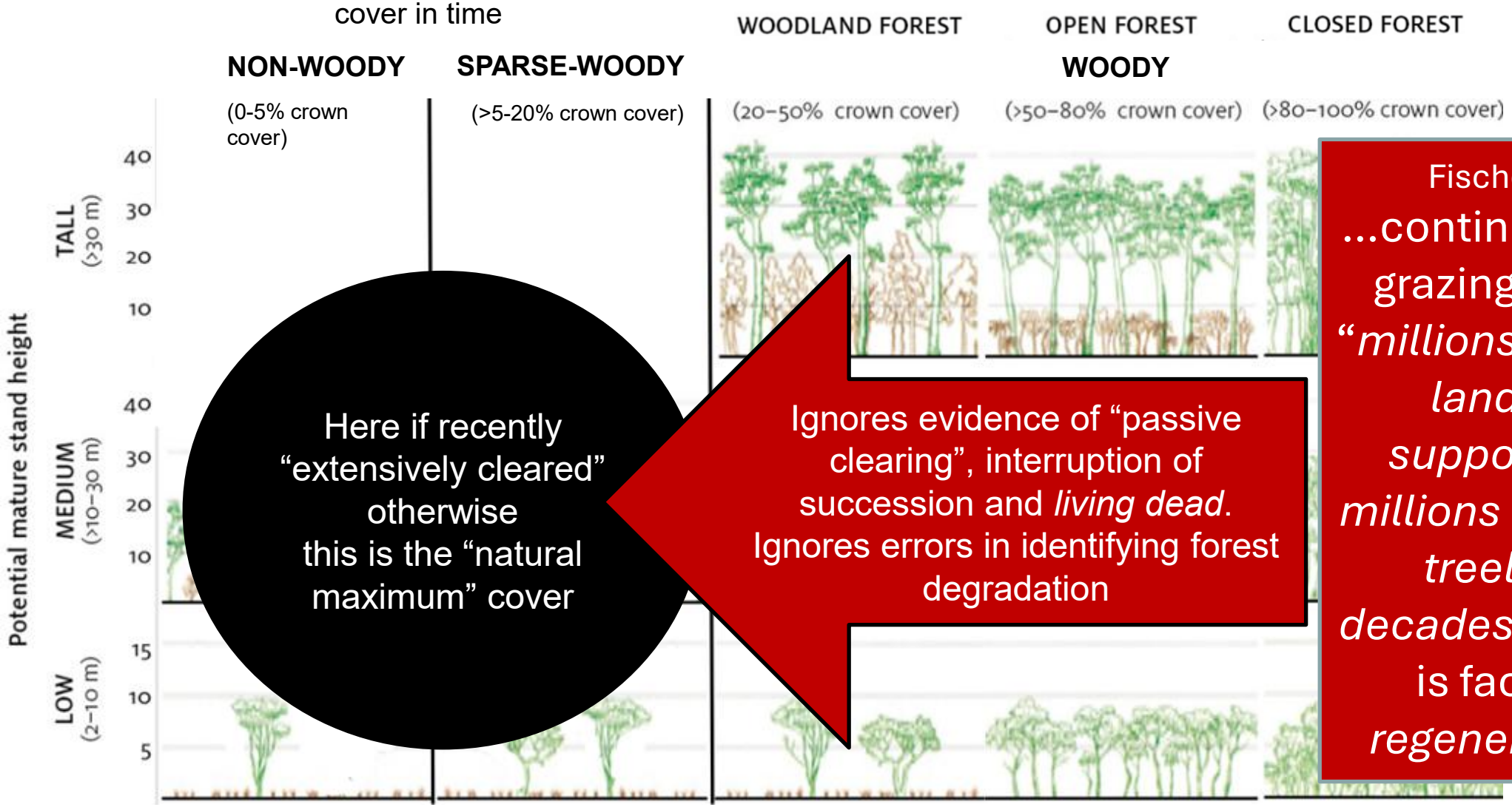
Classified as Forest (if at least 0.2 ha)



Here if recently “extensively cleared” otherwise this is the “natural maximum” cover

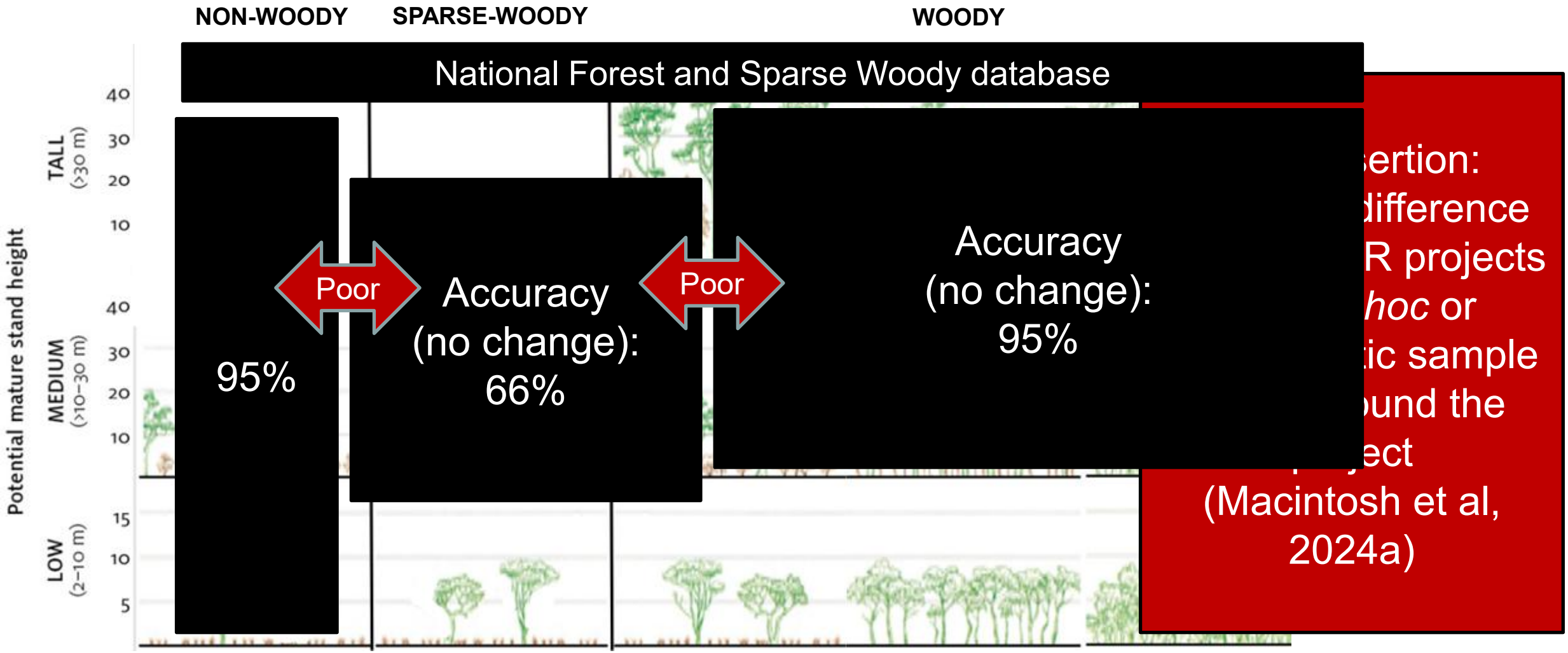
Ignores evidence of “passive clearing”, interruption of succession and *living dead*. Ignores errors in identifying forest degradation

Fischer et al (2009)

…continuous livestock grazing will result in “*millions of hectares of land currently supporting tens of millions of trees will be treeless within decades*” as the region is facing “*a tree regeneration crisis*”.

Criticism #2: no “additionality”

Measurement compromises: instruments



Is NFSW a “useful” model? (a)

Table 1 | Confusion matrix comparing classification results between NFSWVD (rows) and reference lidar dataset (columns) for 500 validation points, with associated omission and commission errors and overall accuracy (OA)

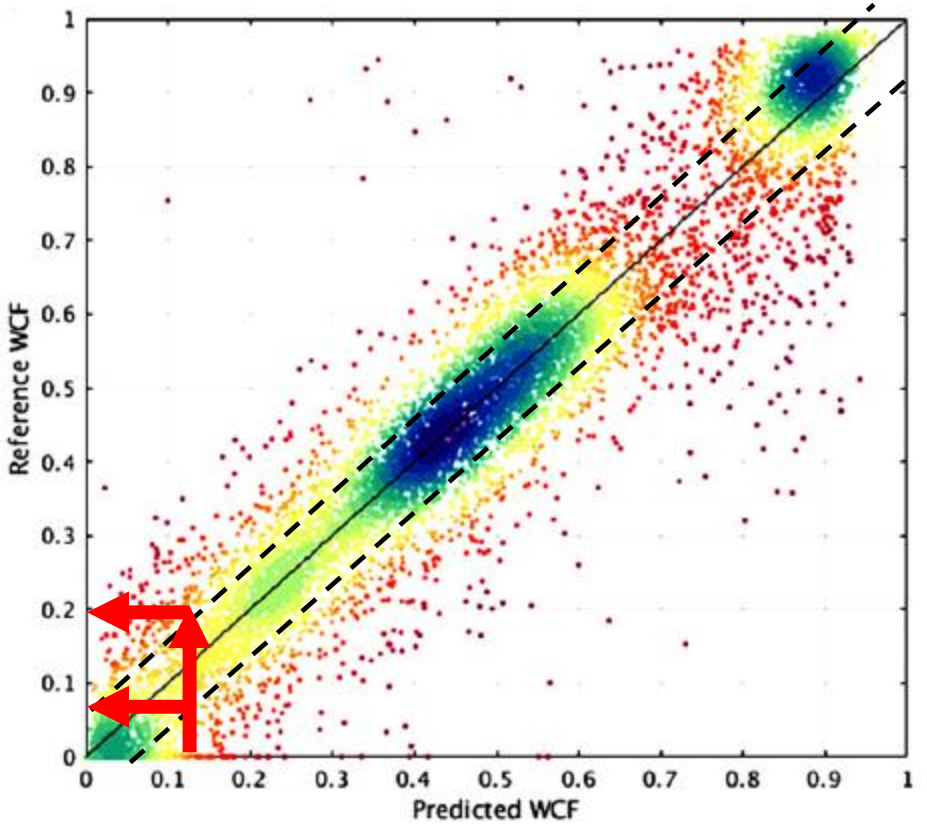
		Reference lidar				
		Non-woody	Sparse woody	Forest	Total	Commission
NFSWVD	Non-woody	131	97	42	270	51.5%
	Sparse woody	4	22	55	81	72.8%
	Forest	6	14	129	149	13.4%
	Total	141	133	226	500	
	Omission	7.1%	83.5%	42.9%		OA: 56.4%

Moore et al (2025)

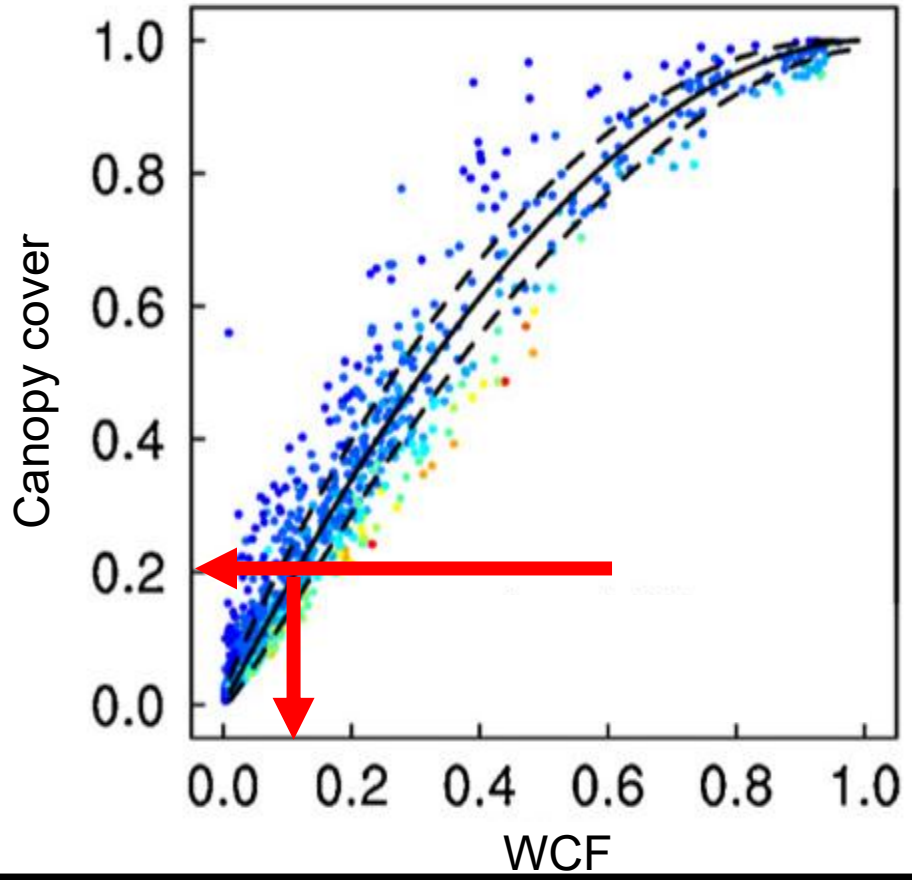
Is another national model useful?

Woody Cover Fraction (Liao et al, 2020) RMSE=0.07

Woody Cover Fraction -> Canopy Cover (Fischer et al, 2018) RMSE=0.07



Combined RMSE
$= \sqrt{0.07^2 + 0.07^2}$
≈ 0.1



Such a RSME inflates type I error and reduces power of test (H_0: $\ddot{u}_a = \ddot{u}_b$ not able to reject)

Does NFSW support WCF?

Macintosh et al (2024b) undertook WCF analysis of canopy in HIR projects to provide *a way of cross-checking the results from Macintosh et al (2024a)* that relied on NFSW to assert that there was no difference between HIR and ad hoc samples

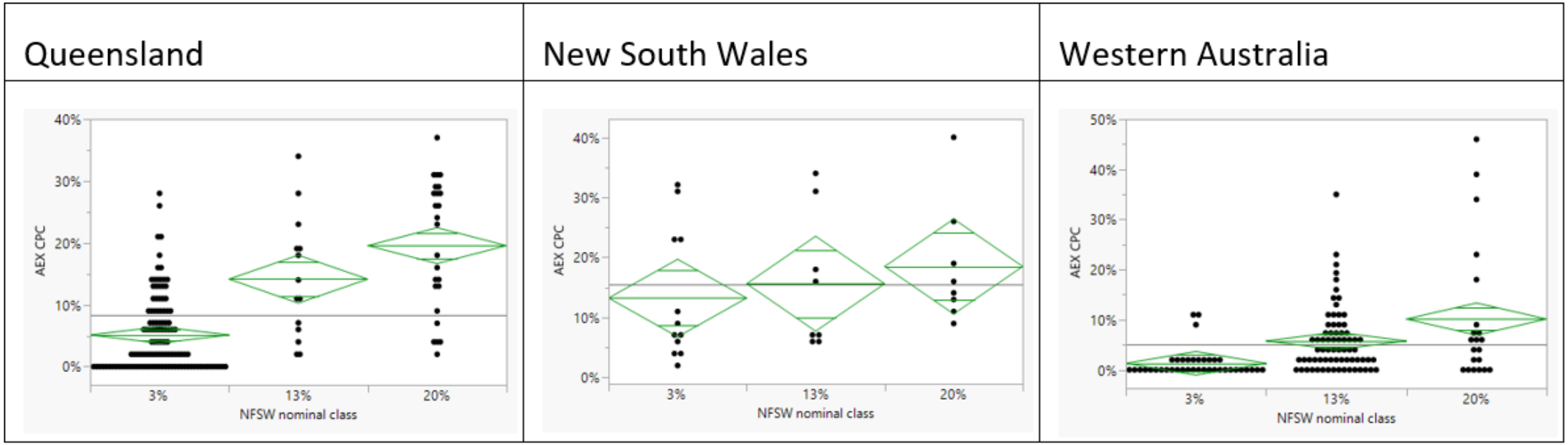
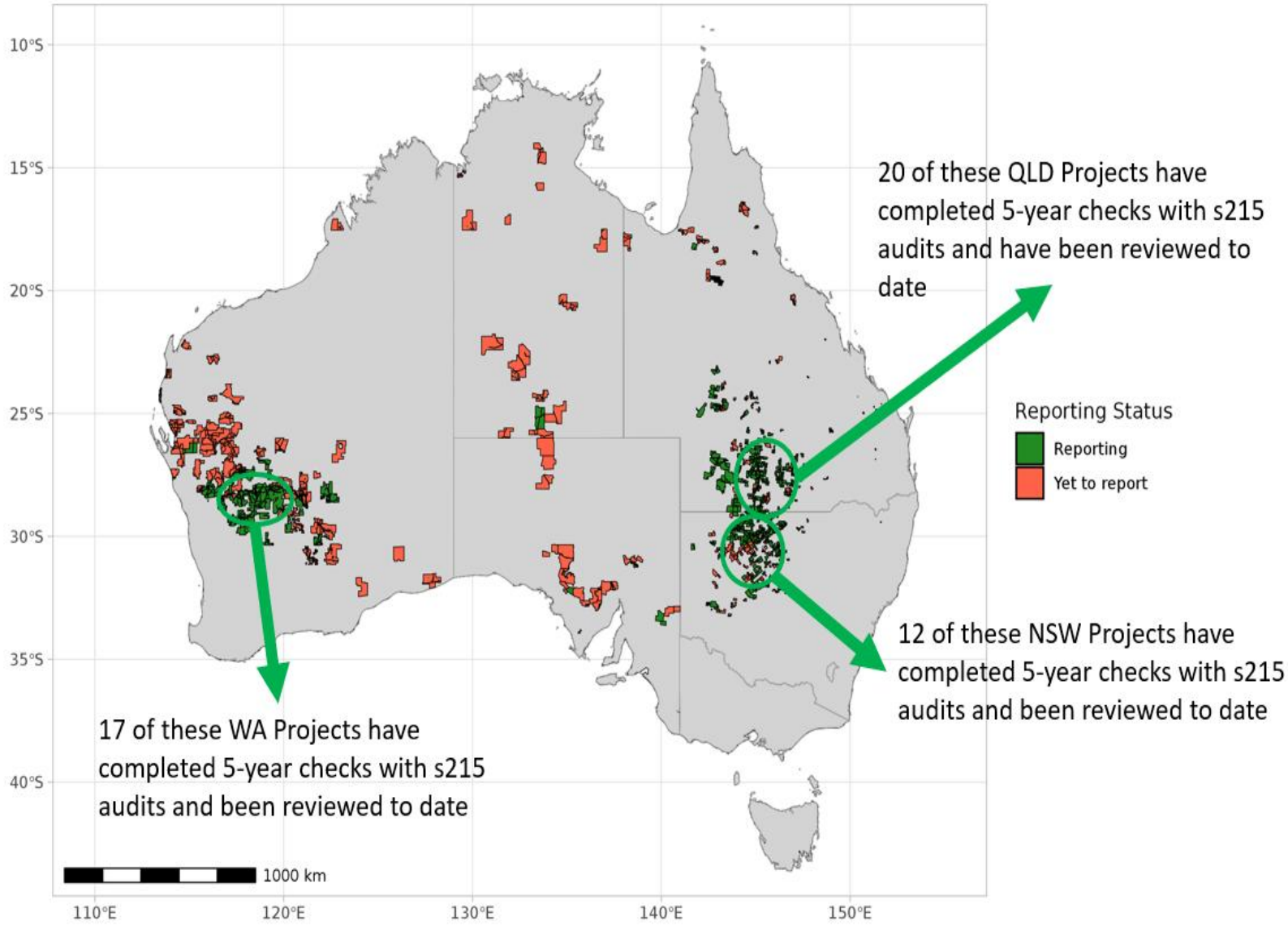


Figure 4: ANOVA of canopy cover estimated from AEX by NFSW classes (nominal values for non-woody, sparse-woody and woody respectively) for each State.

What do HIR proponents do?

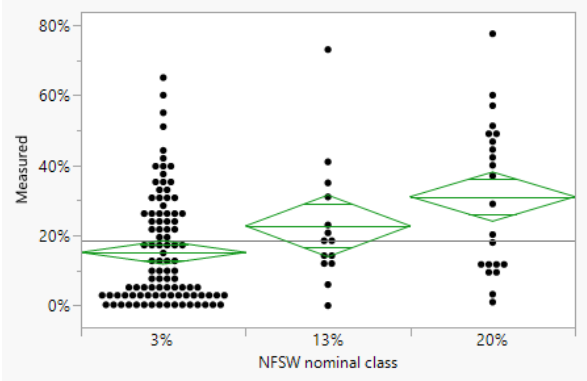
- Required to produce evidence that:
  - Forests / forest species are present in the locality
  - Map out CEA; baseline/pre-existing forest; non-project area
  - Management changes occurring to support regeneration
  - Regeneration is meeting 5-yearly targets:
    - Minimum canopy cover or change thresholds
    - Minimum stocking of appropriate species
  - **Good practice mapping with minimum 85% accuracy:**
    - **Satellite with 1 – 10 m resolution; aerial photographs; LiDAR**
    - **Local calibration / ground truthing**
- Get audited and reviewed
  - …multiple times

What does CER do?



Is NFSW a “useful” model? (b)

Queensland



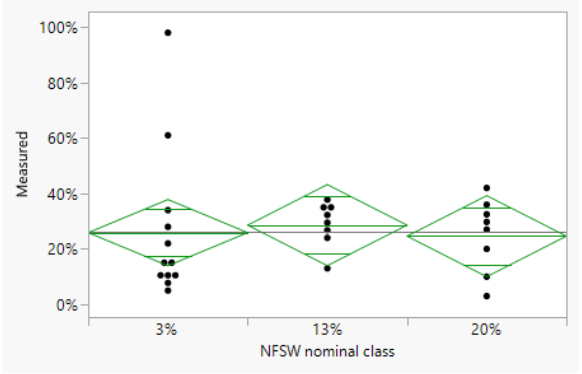
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
NFSW nominal class	2	0.4795977	0.239799	8.6592	0.0003*
Error	131	3.6277727	0.027693		
C. Total	133	4.1073704			

Classification accuracy:
Non-woody: 42%
Sparse-woody: 50%
Woody/Forest: 59%

Canopy Cover (class mean):
Non-woody: 15%
Sparse-woody: 23%
Woody/Forest: 31%

New South Wales



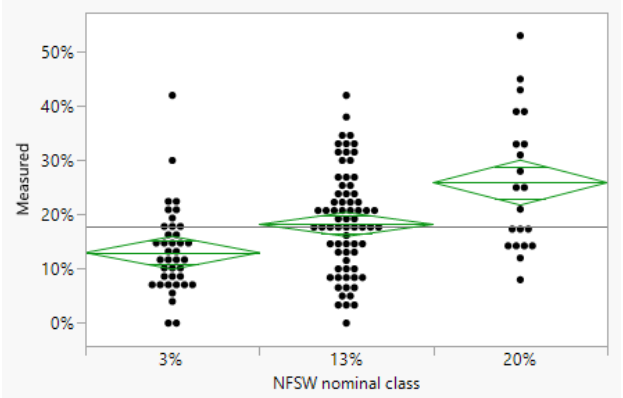
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
NFSW nominal class	2	0.0066684	0.003334	0.0827	0.9209
Error	25	1.0080515	0.040322		
C. Total	27	1.0147199			

Classification accuracy:
Non-woody: 8%
Sparse-woody: 13%
Woody/Forest: 75%

Canopy Cover (class mean):
Non-woody: 26%
Sparse-woody: 27%
Woody/Forest: 25%

Western Australia



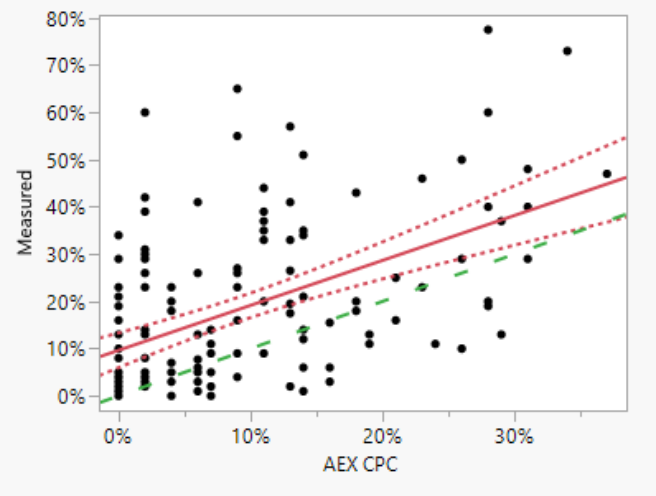
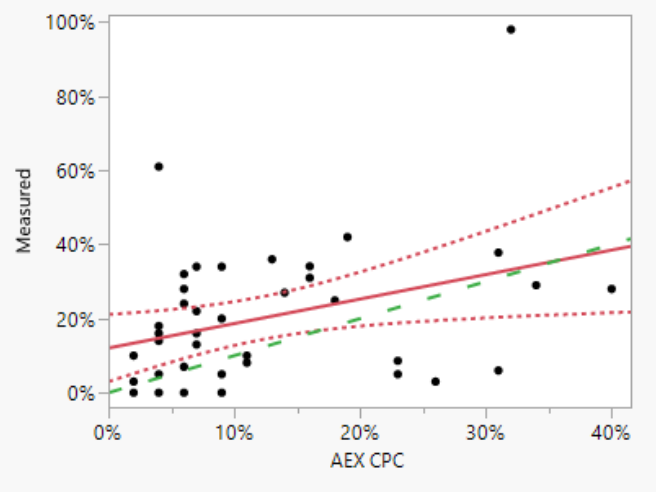
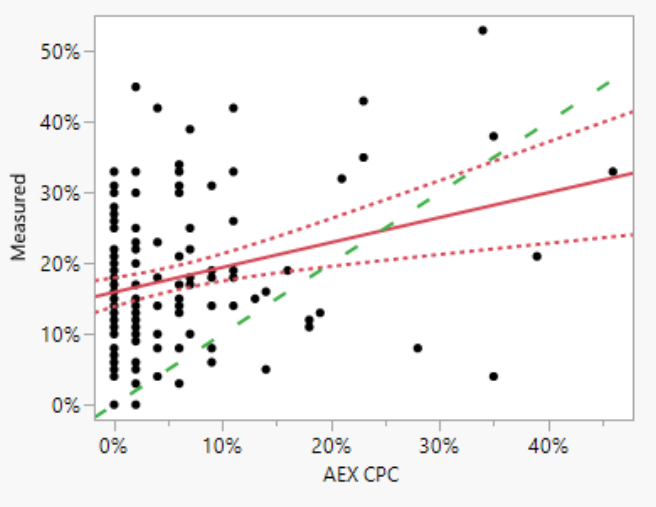
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
NFSW nominal class	2	0.2297976	0.114899	12.5056	<.0001*
Error	130	1.1944099	0.009188		
C. Total	132	1.4242075			

Classification accuracy:
Non-woody: 10%
Sparse-woody: 53%
Woody/Forest: 57%

Canopy Cover (class mean):
Non-woody: 13%
Sparse-woody: 18%
Woody/Forest: 26%

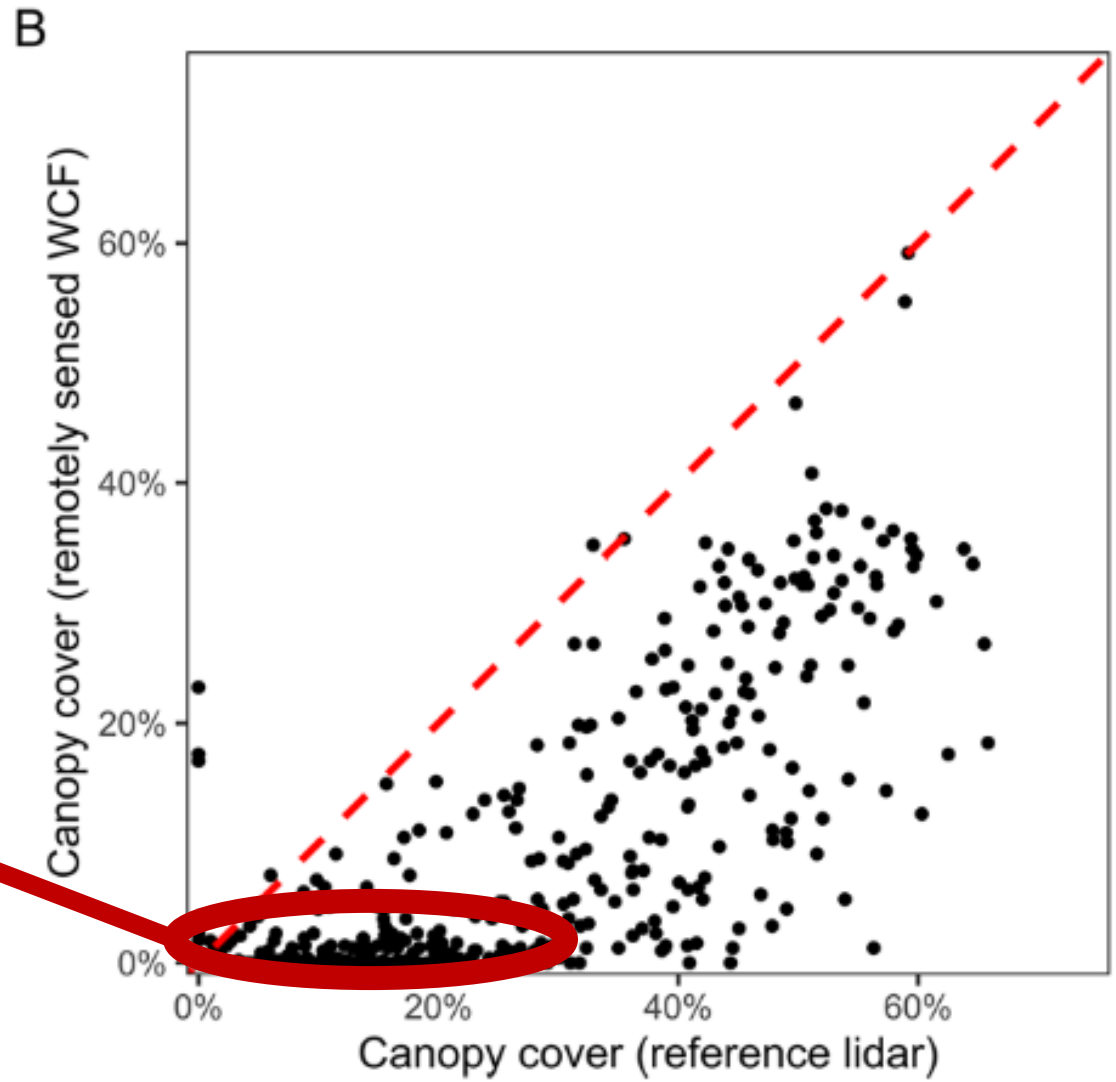
Is WCF / CPC a useful model?

Queensland	New South Wales	Western Australia
		

There are significant correlations, but not 1:1 and with RSME more than 20%

Useful as auxiliary variable in multi-phase inventory but NOT to predict canopy cover without correction

WCF without correcting to Canopy?



Moore et al (2025)

Substantial underestimate / bias in the lower cover areas

Conclusions

- Strong evidence over-grazing disturbs succession; degrades forest;
- Strong evidence controlling grazing has high probability of returning land to more similar pre-grazing condition;
- National-scale, satellite-based and low precision models unlikely to identify regeneration or degradation;
- High quality data (good resolution satellite; LiDAR; ground-based) and good sampling/inventory essential to monitor change in sparse-woody
- Errors must be adequately dealt with

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