Modelling forest mortality risk

Moving from landscape to forest; moving from description to action

Michael Battaglia | Group Leader Adaptation and Mitigation, Global Change Program

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Precision agriculture preceded precision forestry

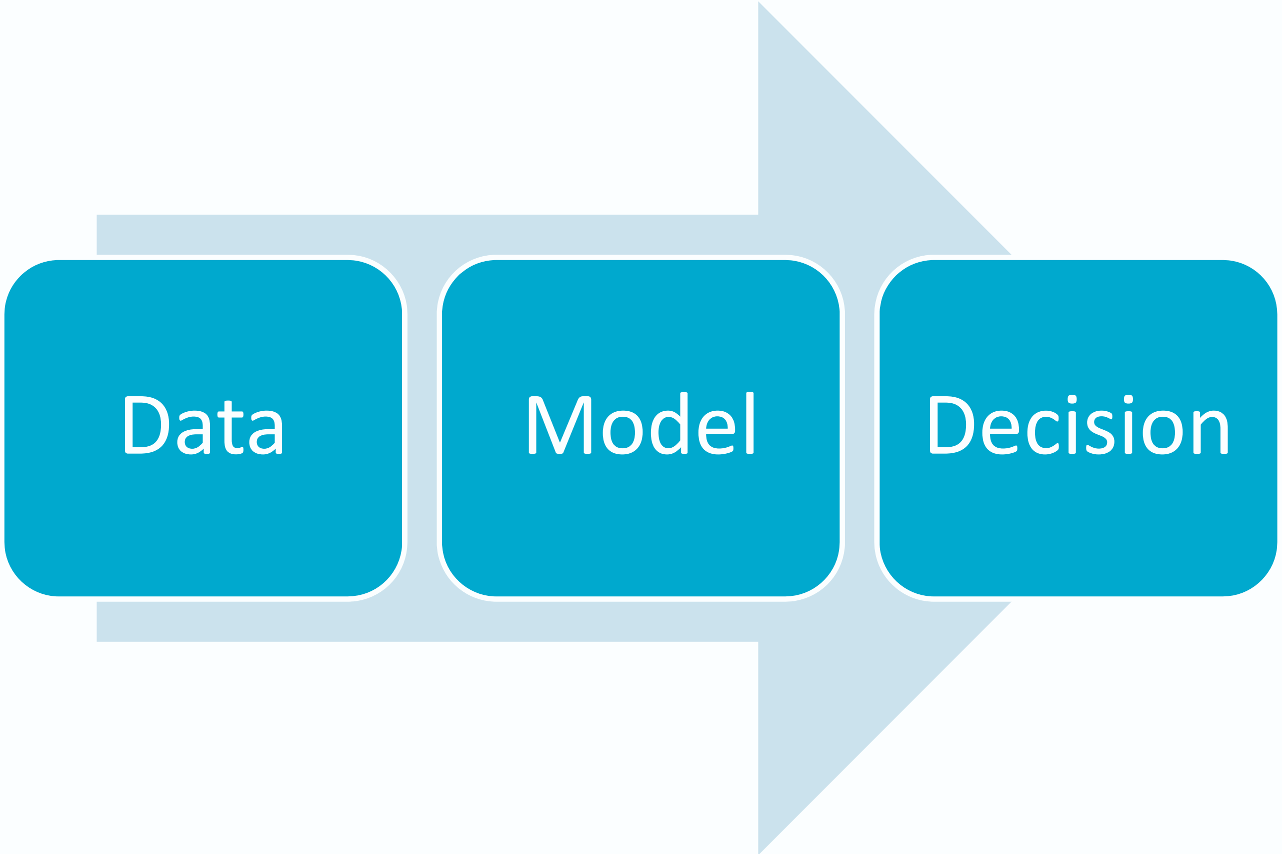
- Precision agriculture was more a concept based on observing, measuring and responding to inter and intra-field variability in crops
- Precision forestry more akin to smart agriculture – the use of modern technology to get as much real information as possible to implement decisions and monitor performance
- Fundamentally about shift from prescription forestry to data driven decisions

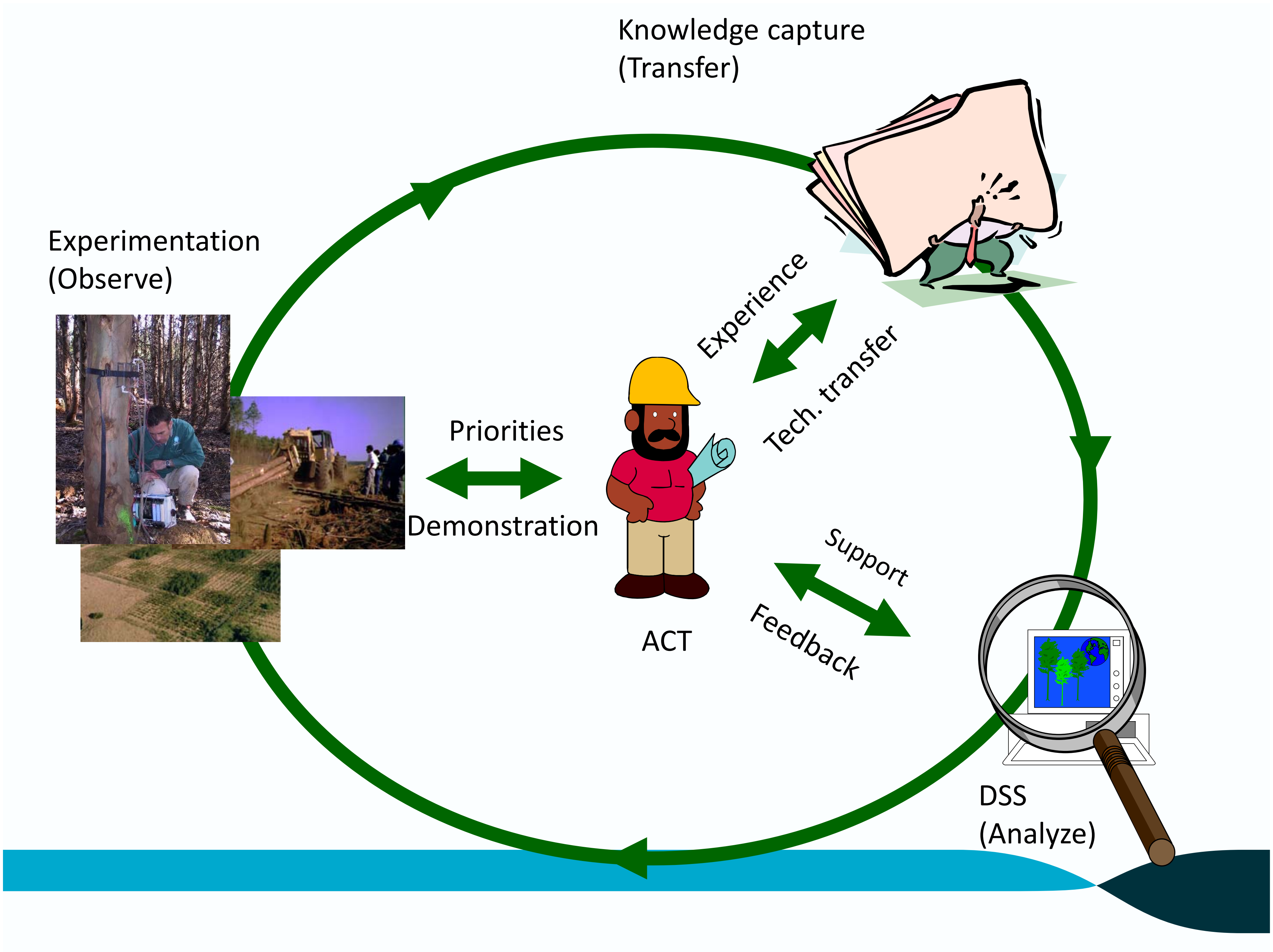
Data driven decisions: desiderata

Data → Decision

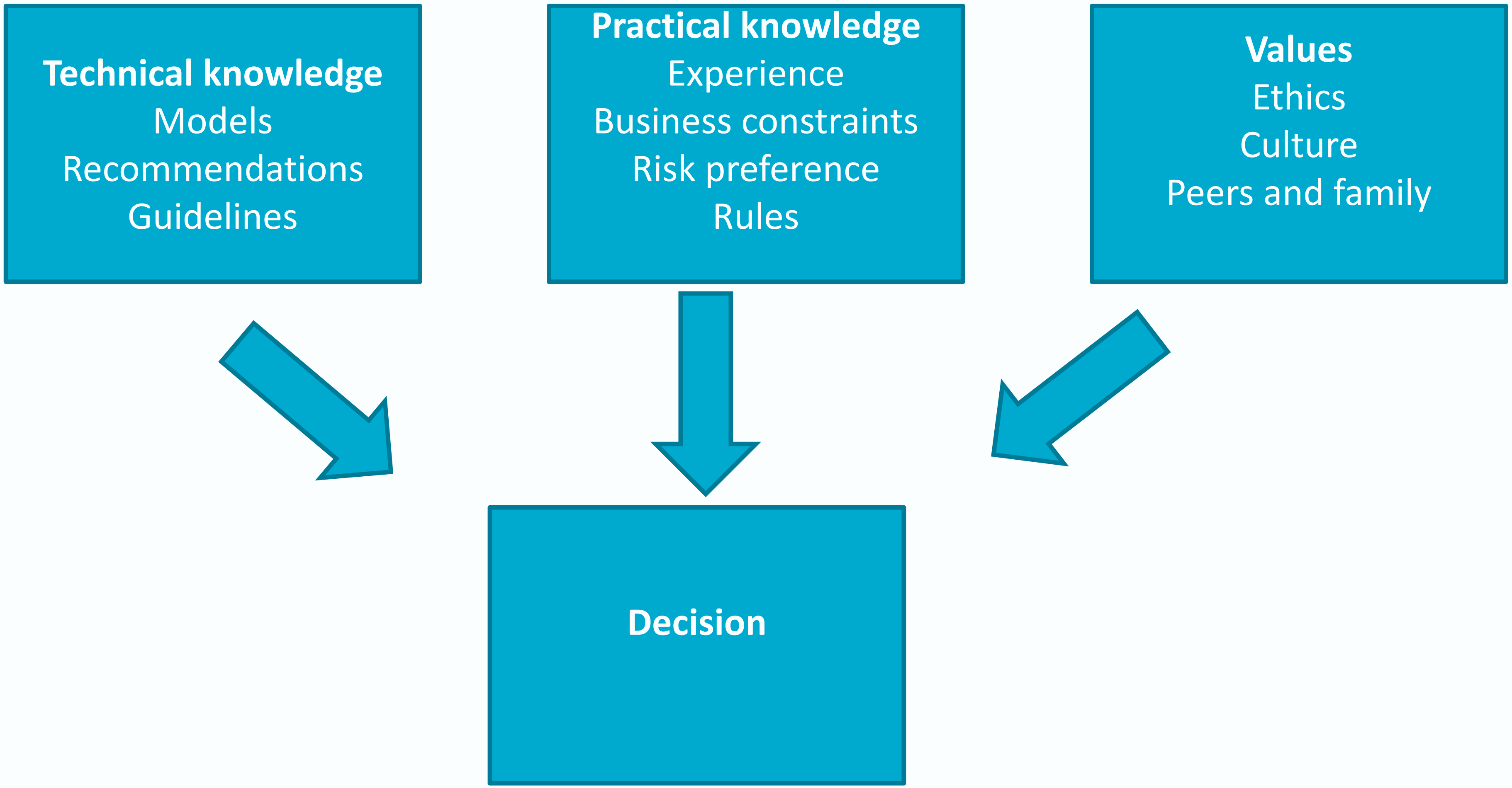
- Reproducible
- Transparent
- Robust
- Reflexive
- Actionable

Models can play an important link

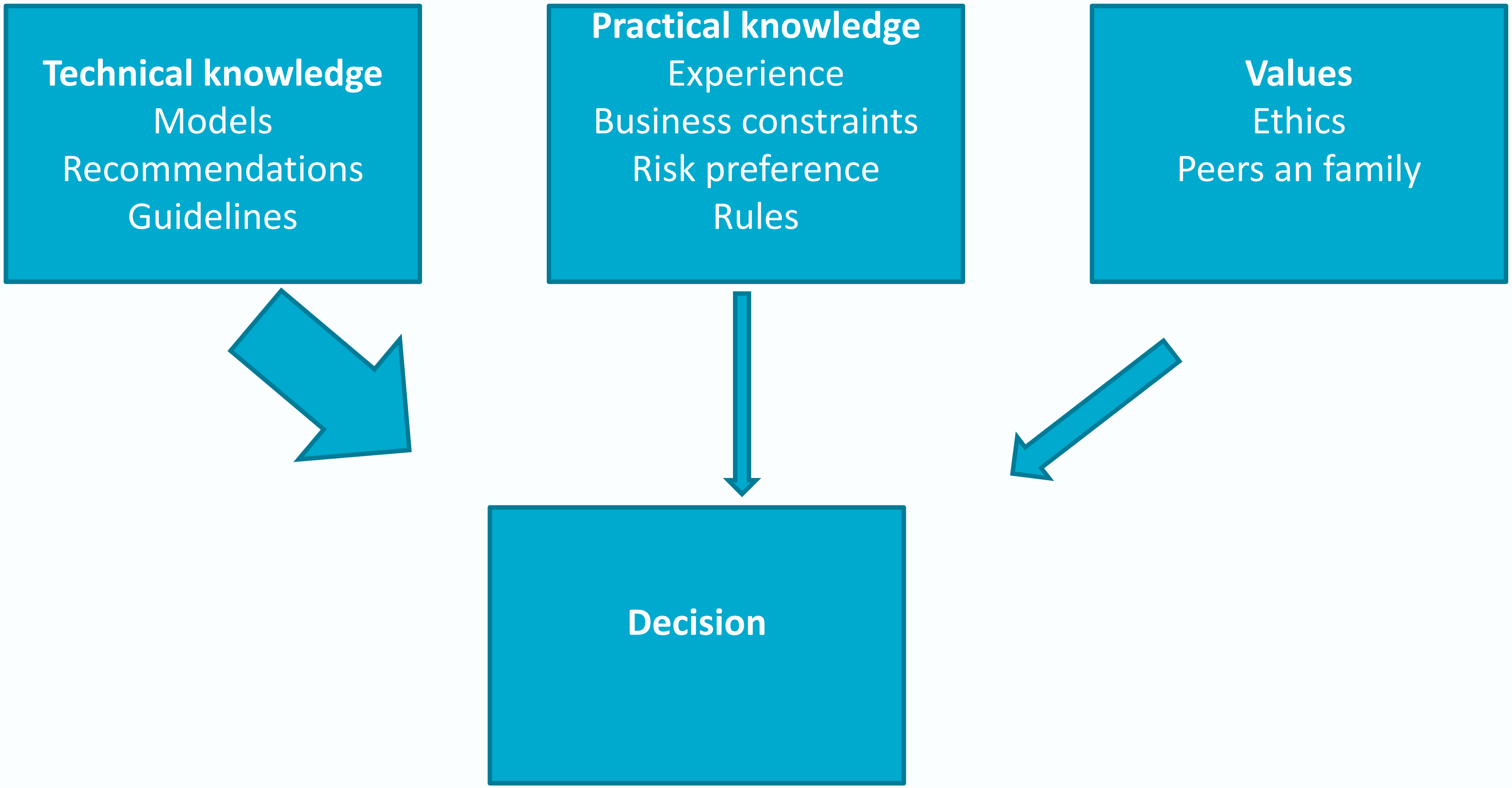




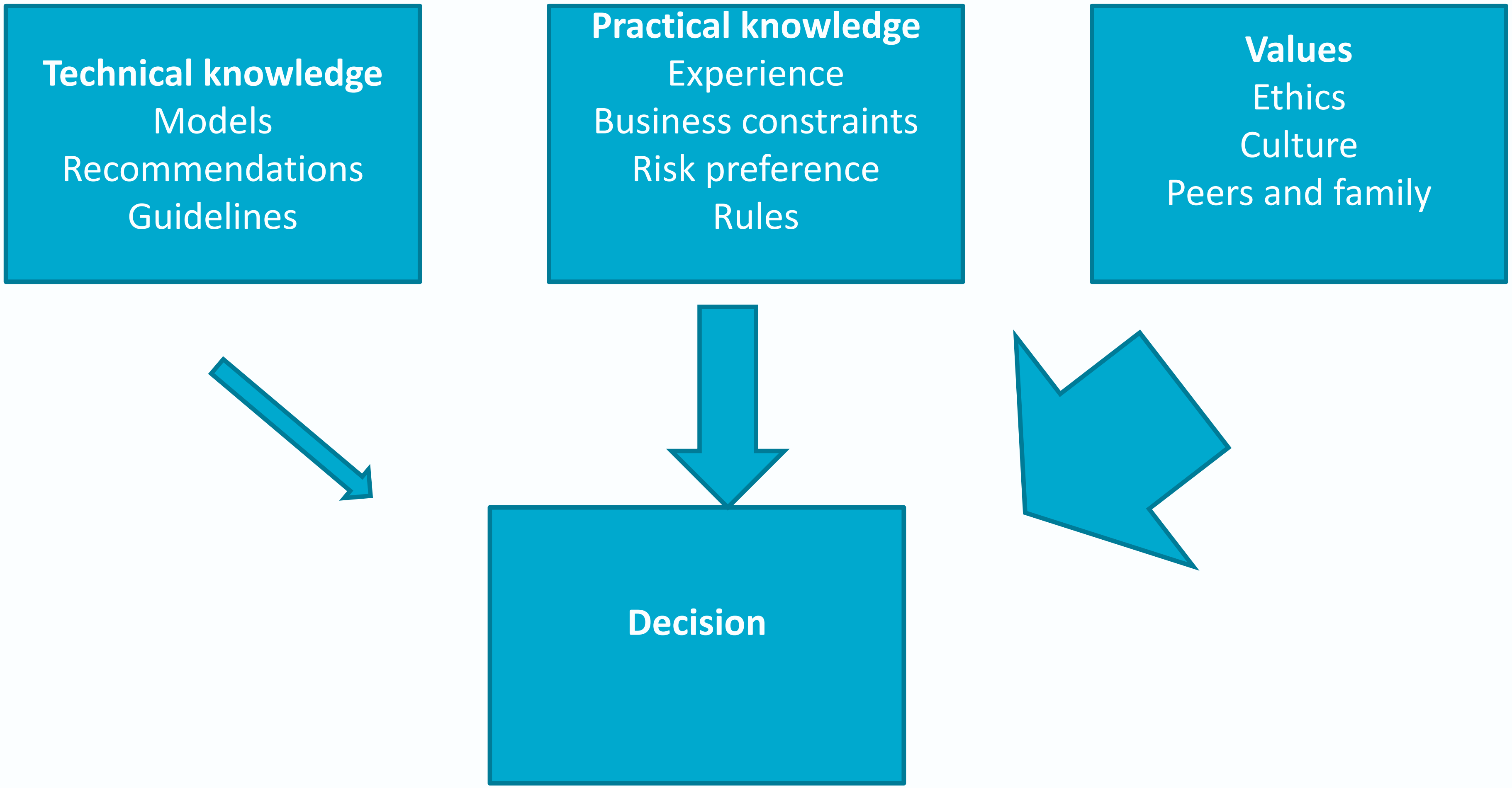
Knowledge capture
(Transfer)
Experimentation
(Observe)
Experience
Tech. transfer
Priorities
Demonstration
Support
Feedback
ACT
DSS
(Analyze)


Technical knowledge
Models
Recommendations
Guidelines
Practical knowledge
Experience
Business constraints
Risk preference
Rules
Values
Ethics
Culture
Peers and family
Decision

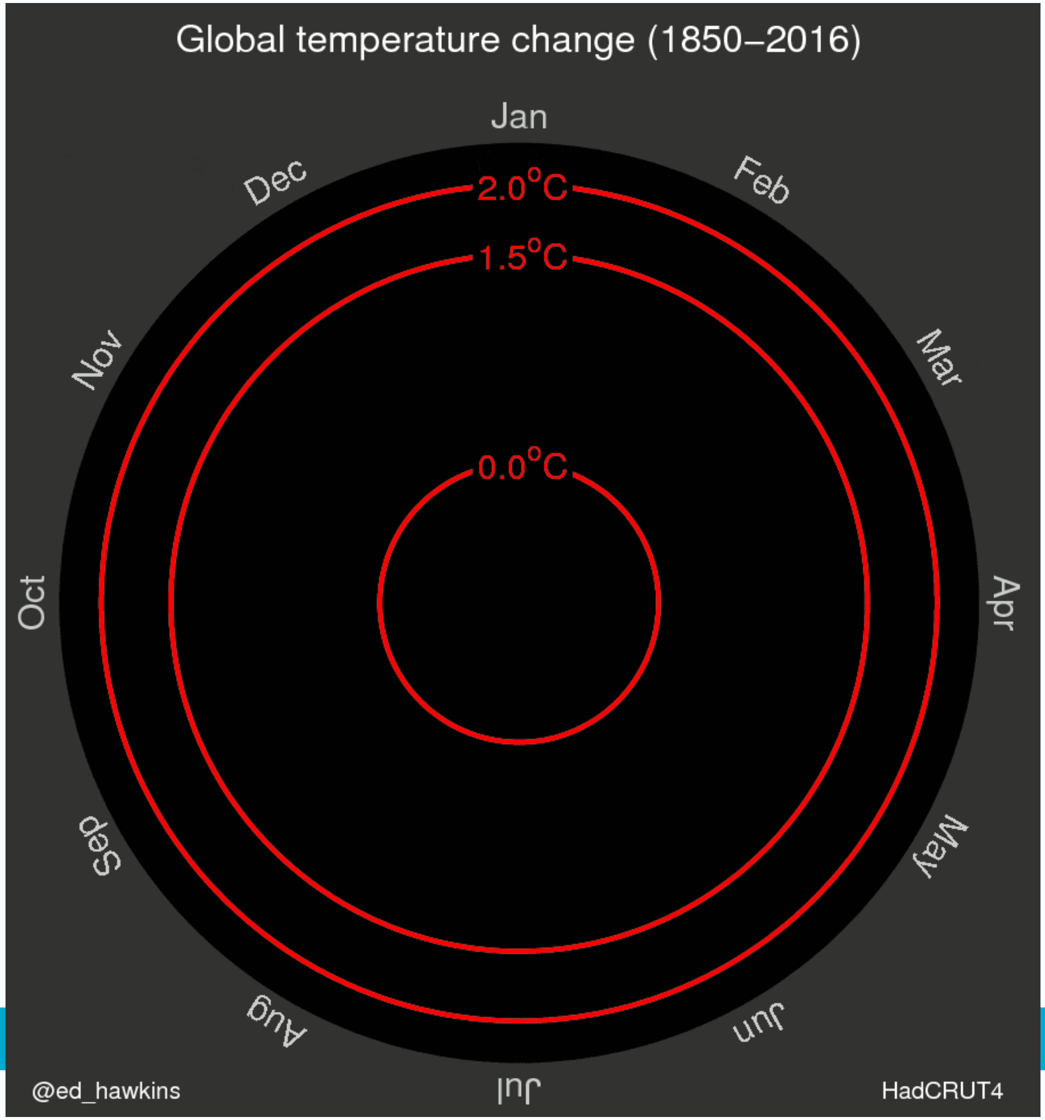
Decisions about buying toasters



Decisions about who to marry



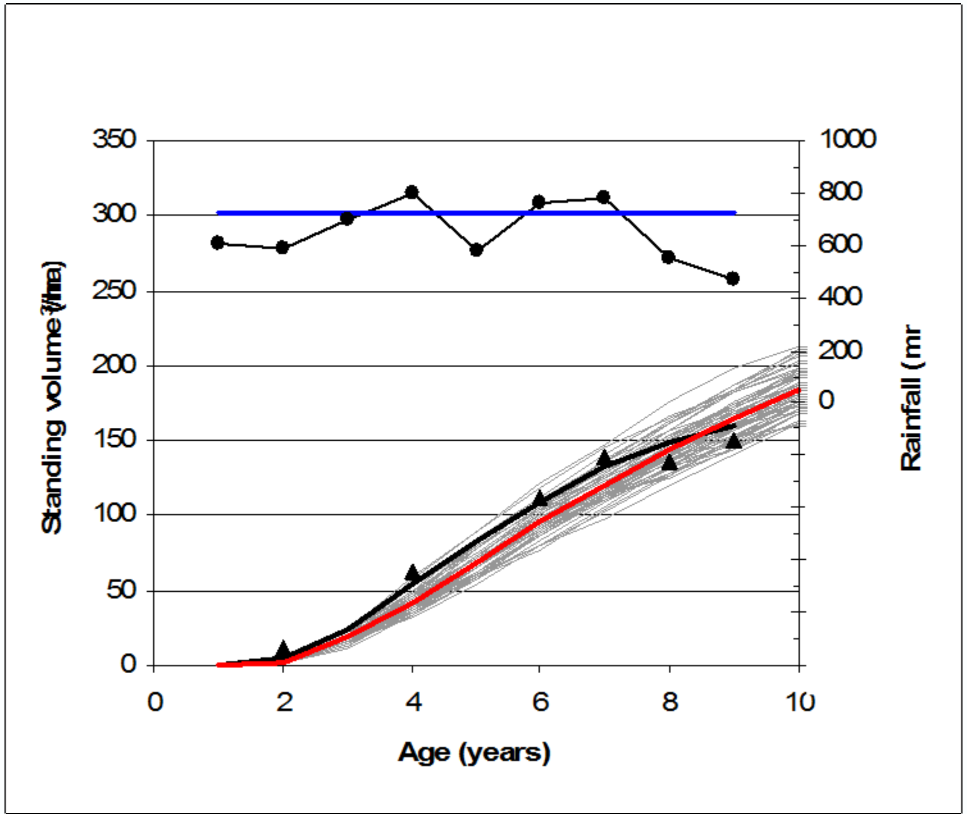
We are all being asked to make decisions about an uncertain climate future: a case study



Forest adaptation is complex (*c.f.* agriculture at least). Decisions need support

- Trees are long-lived, intervention points are few
- Our understanding is poor and the system complex
- In additional to incremental change, system has thresholds that result in step changes
- Adaptation must take place across the value chain
- Landscape level connections
- We are adapting while climate change is ‘being done to us’

The world is full of unique observations, making sense of these requires integration and synthesis – especially for drought and climate extremes our data is very sparse



(▲) observed data

(▬) the volume curve that CABALA predicts from the weather that occurred during the rotation

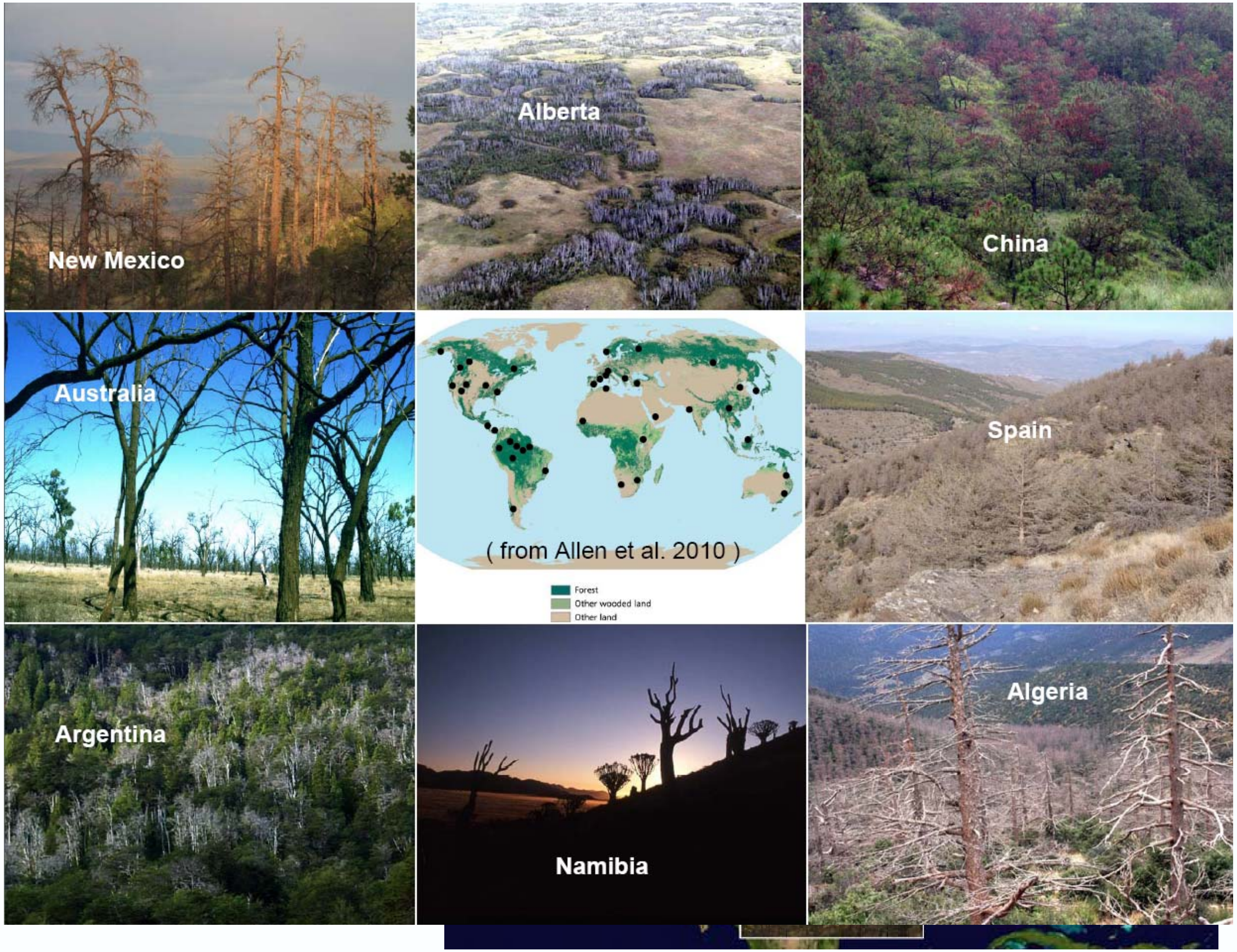
(▬) are possible growth trajectories that might have occurred planting each year from 1940 to the 1998

(▬) long term average production

(▬) is mean annual rainfall for the period 1940 to 2006

(●) rainfall during observed rotation

Widespread Tree Mortality



C.D. Allen *et al.* (2010) Forest Ecology and Management

Modelling can help: and example with drought mortality and climate change

- Reproducible: we can keep workflows and show how decisions were reached
- Transparent: assumptions are explicit, and can be built upon, decisions are based on a risk assessments that can be presented
- Robust: we can define the limits to adaptation
- Reflexive: we can learn from new experience, we can design investigative studies, to reduce gap between possible and plausible.
- Actionable: we can assess and quantify management actions, at the scale (local) that actions are implemented

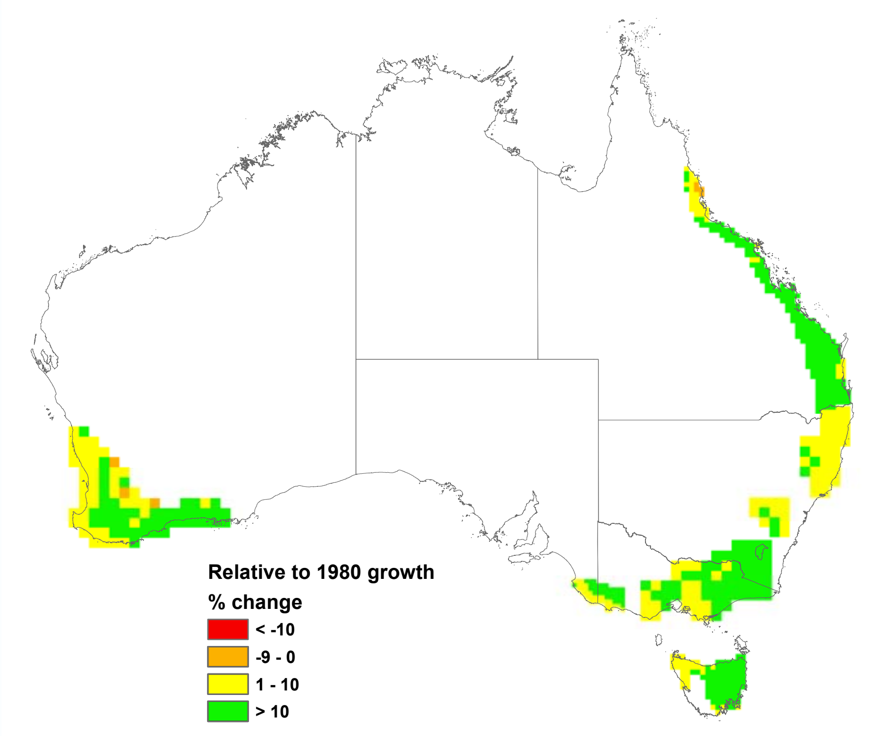
- Participatory: we can design interactive what-if discussions, and create a meeting point for technical and practical knowledge

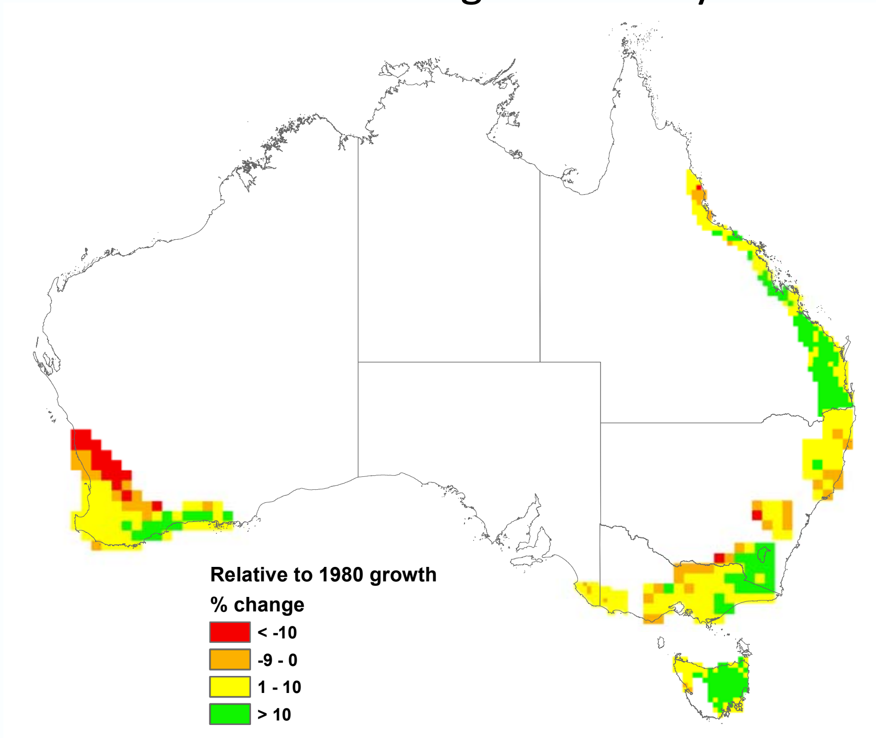
Papers that ignore mortality or key processes such as eCO2


Not robust
Australian Government
Australian Bureau of Agricultural and Resource Economics and Sciences
Potential effects of climate change on forests and forestry in Australia
August 2011
SUSTAINABILITY & RESOURCES
FAO CORPORATE DOCUMENT REPOSITORY
Title: Adapting to climate change...
Produced by: Forestry Departme
Español Français
ASSESSING POSSIBLE IMPACTS OF CLIMATE CHANGE ON SPECIES IMPORTANT FOR FORESTRY IN VIETNAM *
TREVOR H. BOOTH[1], NGUYEN HOANG NGHIA[2], MIKO U. F. KIRSCHBAUM[1], CLIVE HACKETT[3] and TOM JOVANOVIC[1]
Climatic Change 41: 109–126, 1999.
© 1999 Kluwer Academic Publishers. Printed in the Netherlands.
carbon budget of Pinus radiata plantations in south-western
under four climate change scenarios
GUILLAUME SIMIONI,[1,2,3,*] PETER RITSON,[1,2] MIKO U.F. KIRSCHBAUM,[4] JOHN MCGRATH,[1,2] IAN DUMBRELL[5] and BETH COPELAND[5]
Received November 12, 2008; accepted June 11, 2009
Keywords: carbon sequestration, CenW, modelling, net ecosystem exchange, net primary production.
Introduction
A process-based approach to estimate lodgepole pine (Pinus contorta Dougl.) distribution in the Pacific Northwest under climate change
Nicholas C. Coops · Richard H. Waring
Impact of climate change on the distribution of tropical pines in Southeast Asia

Misleading too!

Add in drought mortality





Battaglia et al 2009

Or look for broad surrogates or correlates for tree mortality

Forest Ecology and Management 265 (2012) 94–101

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

ELSEVIER

Managing drought-induced mortality in *Pinus radiata* plantations under climate change conditions: A local approach using digital camera data

Christine Stone [a,*], Trent Penman [b], Russell Turner [a]

[a] Forest Science Centre, Industry & Investment NSW, P.O. Box 100, Beecroft, New South Wales 2119, Australia
[b] Centre for Environmental Risk Management of Bushfires, Institute of Conservation Biology and Environmental Management, University of Wollongong, New South Wales, Australia

ARTICLE INFO

Article history:
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Keywords:
Pinus radiata
Climate change
Drought
Mortality
Airborne imagery

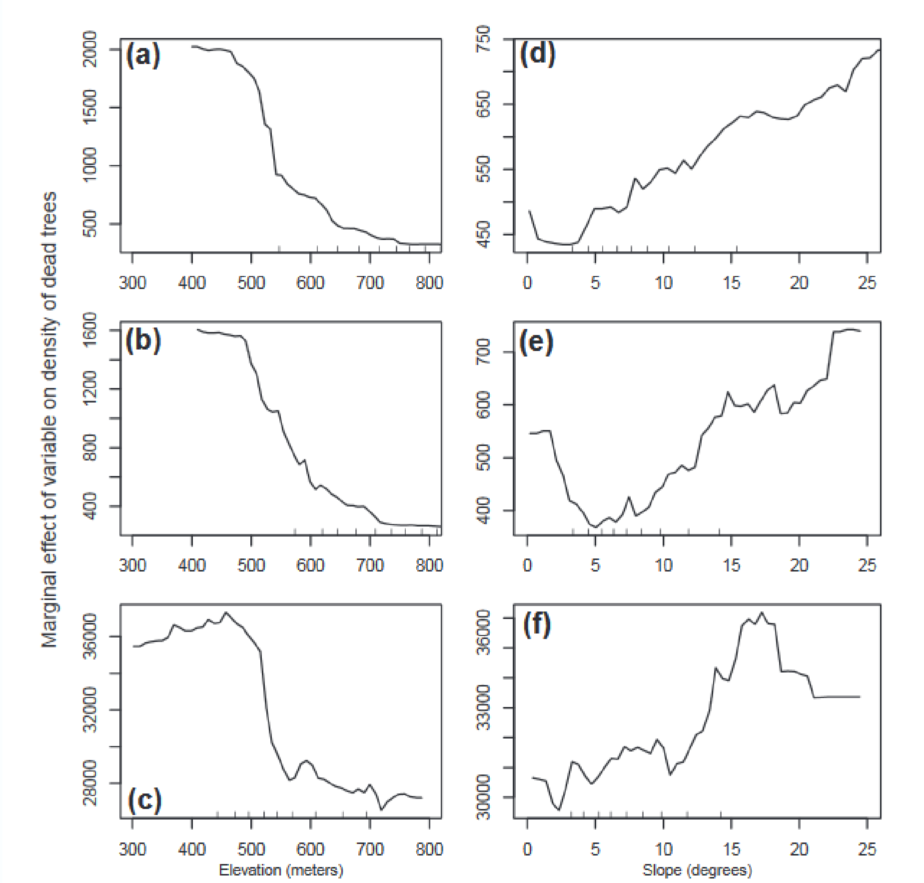
ABSTRACT

Pinus radiata D. Don is an internationally important plantation species. The predicted increases in the frequency, duration and/or severity of drought and heat stress associated with climate change could challenge the commercial viability of *P. radiata* plantations in several countries where existing plantations are grown in districts already vulnerable to periods of drought. We undertook an empirical approach to examine silvicultural and site factors associated with a significant drought-induced mortality event in southern New South Wales, Australia. The aim was to identify local, practical, risk prevention options for *P. radiata* plantations exposed to the climatic conditions predicted for this region. Our approach did not rely on ground-based assessment of plots but rather a total census of dead trees across two study areas totalling 10,000 ha of *P. radiata*, in compartments ranging in age from 0 to 35+ years. Dead tree density counts were derived both manually and automatically from high spatial resolution digital multispectral imagery acquired using a Leica ADS40 Airborne Digital Sensor. The results showed a strong correlation between dead tree densities obtained by the manual detection and the automated process ($R = 0.95$, $P < 0.0001$). Two modelling approaches were applied: random forests (RF) and generalised additive models (GAM). For our study sites, both methodologies identified a similar set of parameters, with time since planting in unthinned stands being the most influential variable, and terrain variables playing a smaller role. Specifically, the models identified a threshold age at around 17–18 years for stands on good quality sites and before age 16 on poorer quality sites before the on-set of catastrophic mortality under severe drought conditions. Both modelling techniques also identified similar trends with respect to elevation and slope, and indirectly, site quality. These site attributes being likely to contribute to water availability. If stands in this area are to be planted at 1000 stems ha^{-1} and thinning schedules cannot be met, then we recommend avoiding sites having a mean elevation of below 600 m or to establish these sites with drought-tolerant genotypes. These recommendations cannot be extrapolated beyond the range of the data. However, the application of robust image classification techniques (e.g. automated tree counts) to high spatial resolution digital imagery, the increasing availability of high resolution climatic, terrain and edaphic GIS datasets, as well as readily available spatial modelling packages, helps off-set the limitations in transferability of our empirical approach.

1. Introduction

Pinus radiata D. Don is now the most widely planted exotic pine

the potential effects of anthropogenic climate change could challenge the commercial viability of plantations in several countries, including Australia, Chile, South Africa and Spain, where existing



Mortality proportion = f{altitude, slope, age, thinning status),
assuming a stationary climate

Forest Ecology and Management 265 (2012) 94–101

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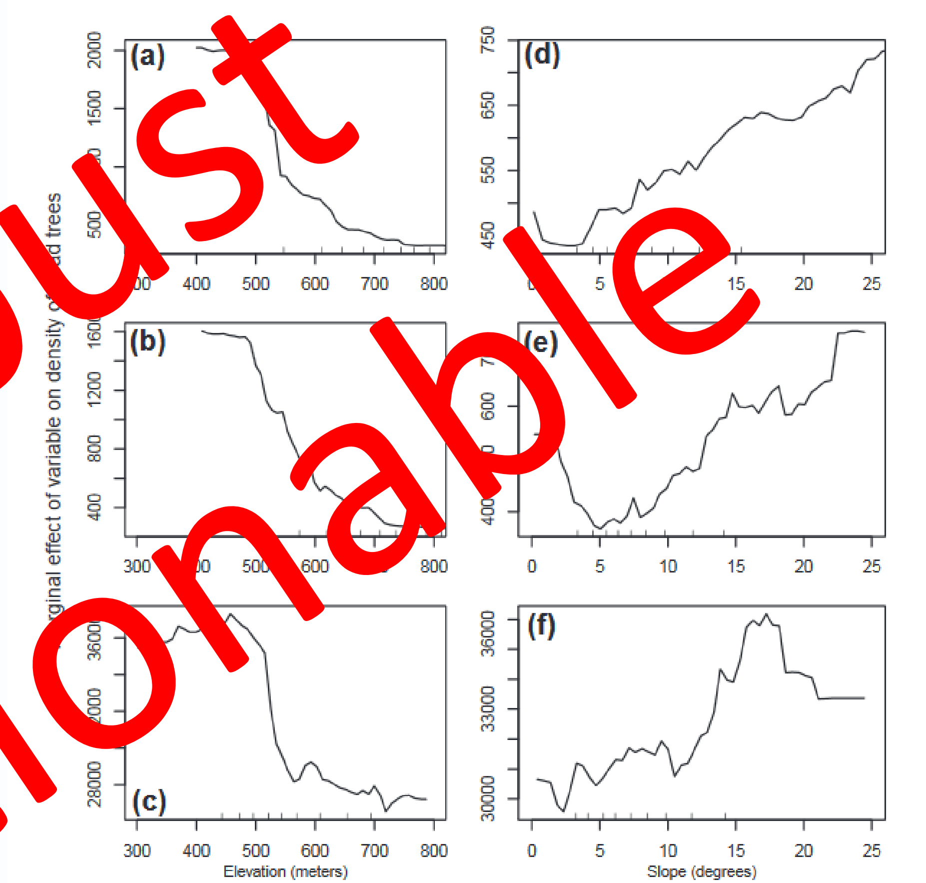
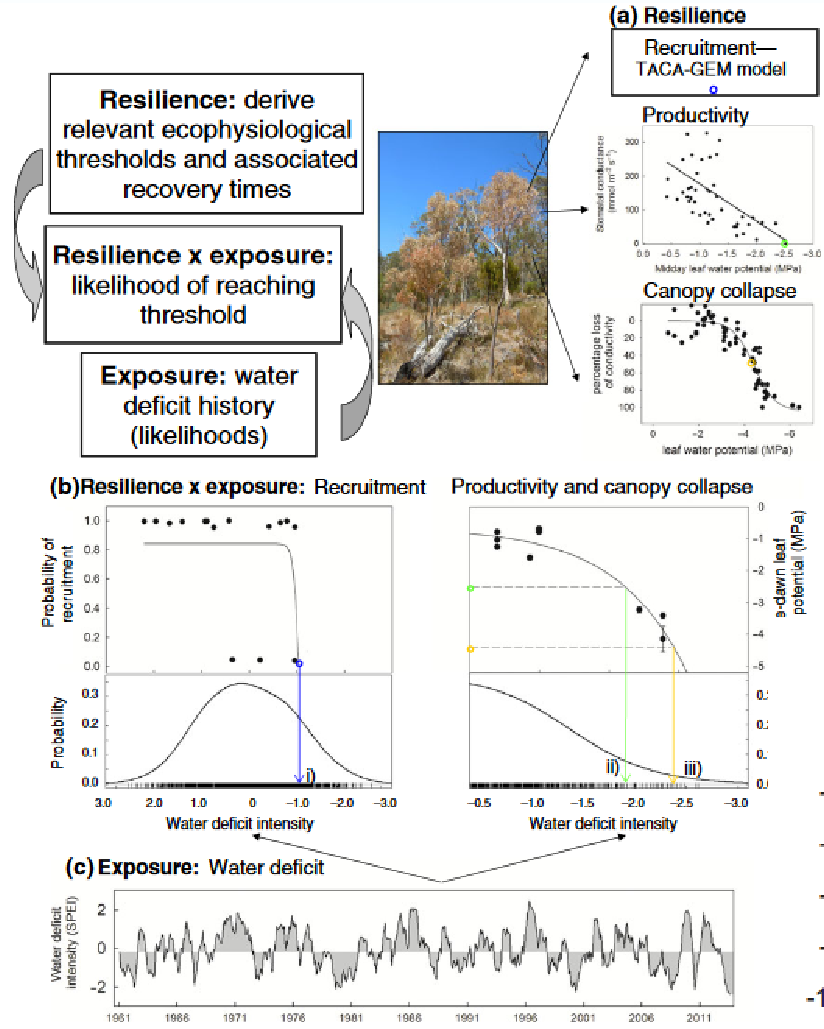


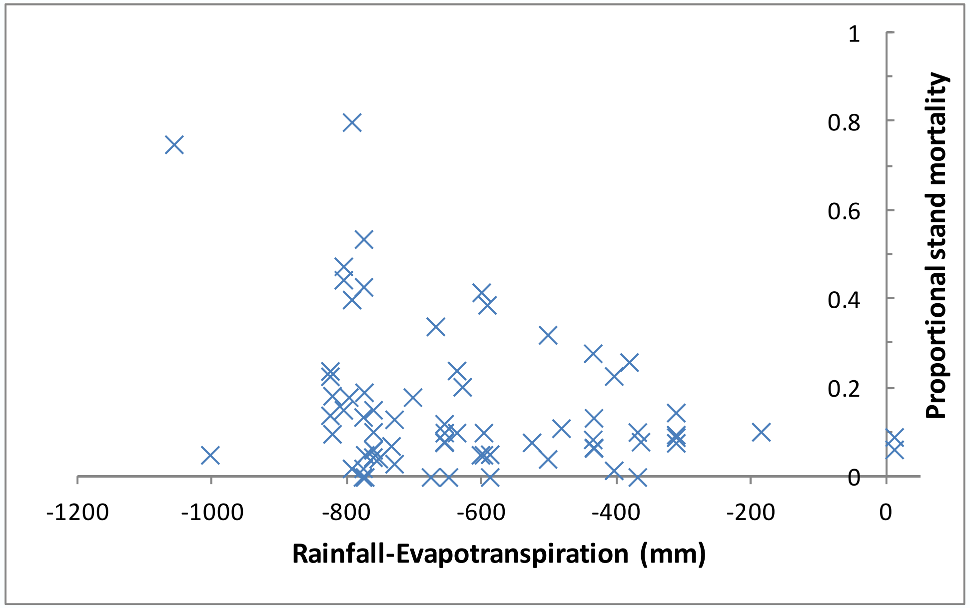
Not robust

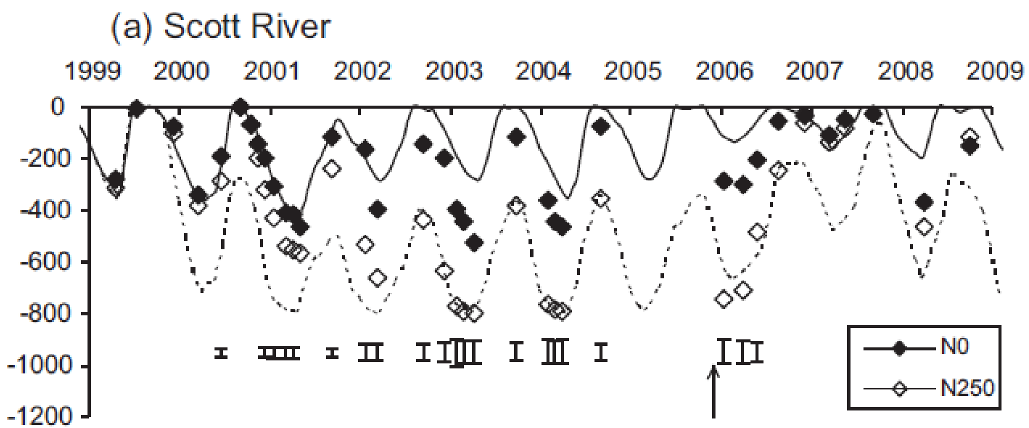
Not actionable

Mortality proportion = f{altitude, slope, age, thinning status),
assuming a stationary climate

But assumes system equilibrium and no local condition effects

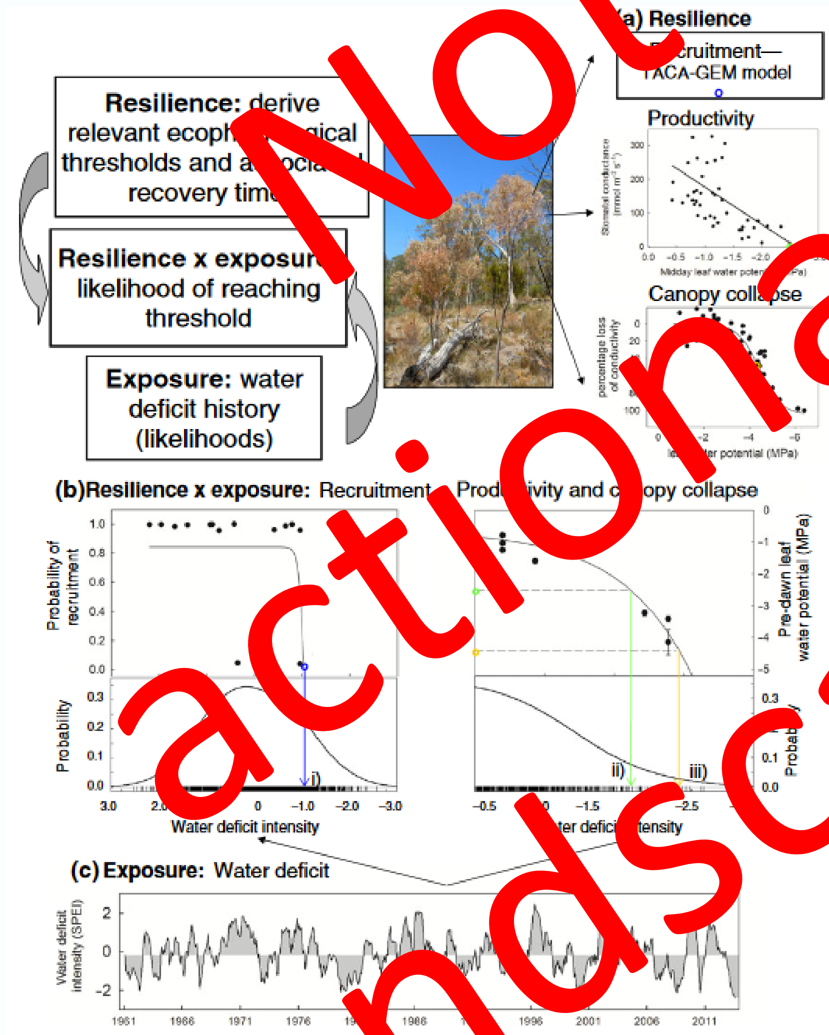






Global Change Biology (2016) 22, 1677–1689, doi: 10.1111/gcb.13177

Not actionable Landscape not forest



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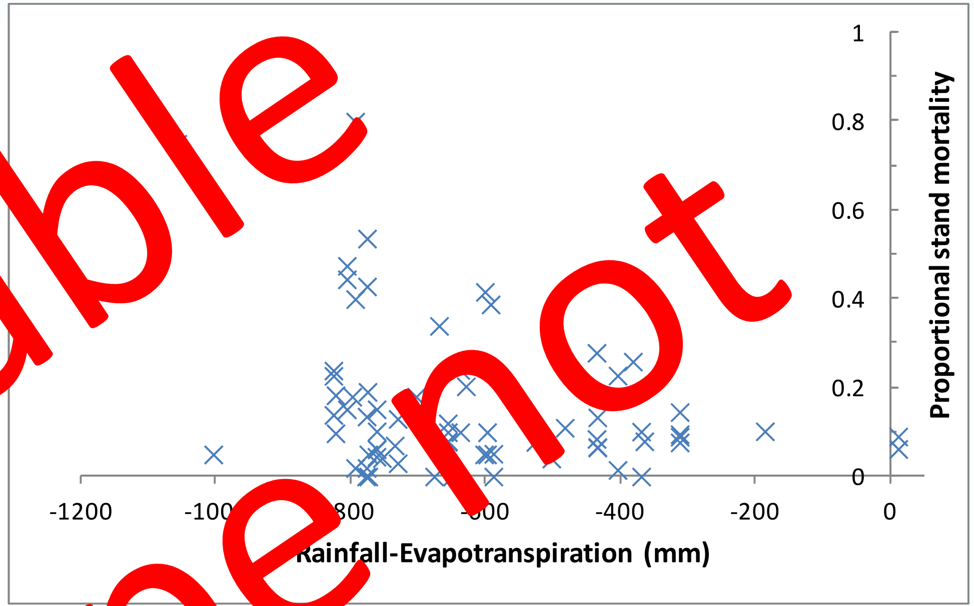
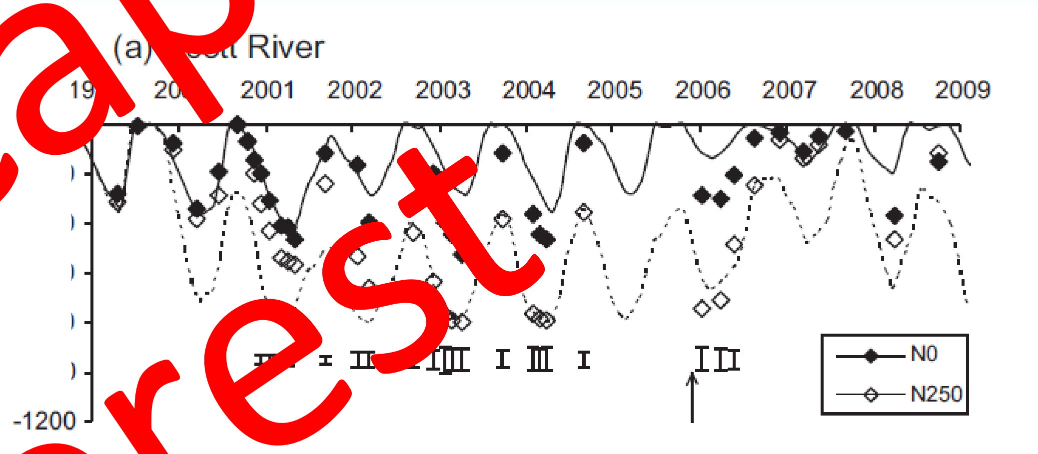




So what are we to do….

………………. Can we progress with the limited experience and knowledge we have?

……………………………..Can Models help us?

………………………………..An Australian example – evidence to decision making.

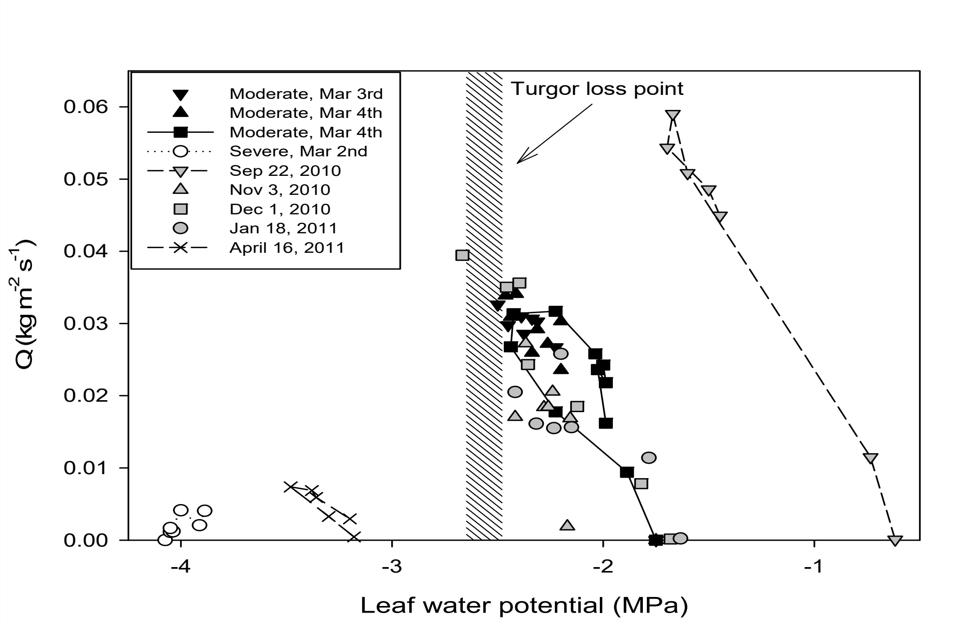
So what is the evidence

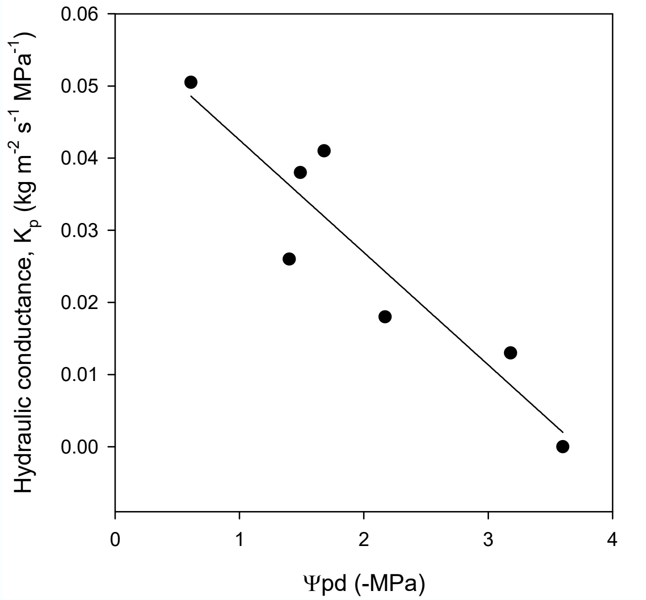
- Not all trees die: it is individuals that die not forests

- Small local differences in conditions matter

- What we do, and the stand state at the time of drought matters

Evidence: we know a lot about plants and how they interact with water stress intensity





Critical thresholds for function

Ψ_{soil} > TLP – normal operating range, all going well

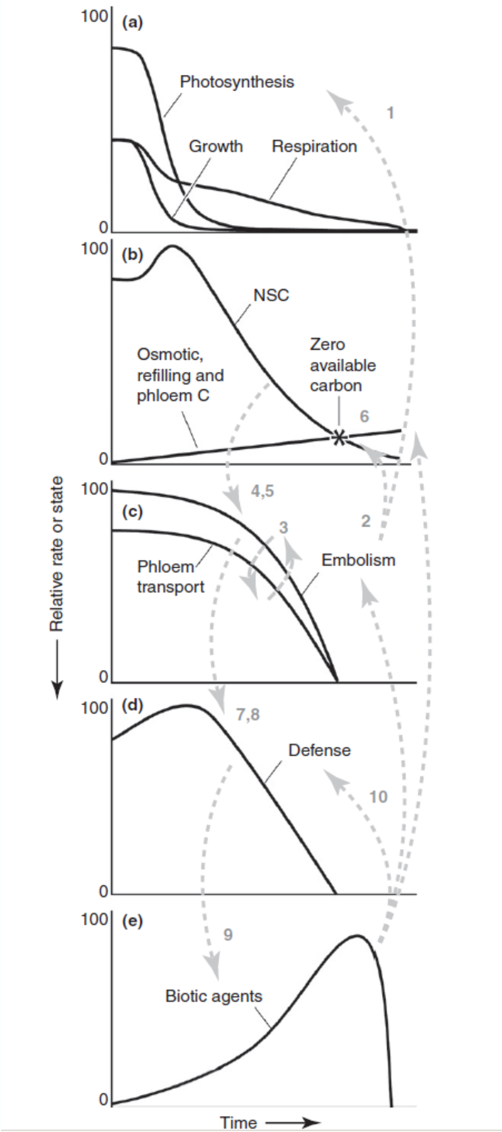
TLP > Ψ_{soil} > Kp=0 – water stressed range: in this range transpiration impeded and plant drawing on carbohydrate stores, we see stomata open for very short periods

Ψ_{soil} < K_P=0 – Critical water stress (hydraulic failure) – plants have lost ability to conduct water and hydraulic failure likely

Evidence: we know plants respond to duration differently, leading to different causes of death

Table 1 Species leaf water potential at turgor loss point and the number of days after drought (DOD) at which pre-dawn leaf water potential reached the tugor loss point.

Species	Turgor loss point (MPa)	Day of drought to TLP	% depletion TNC
E. globulus	-2.2	34	+11%
E. smithii	-2.0	50-60	-14%
P. radiata	-1.6	75-85	-49%



Duration of drought

Mechanistic representations/ conceptualisations consequently are complex, and rarely useful in prediction.

Death is a syndrome not a single cause and event connection ..
…..like health, and like why your rugby team wins or looses, although if your playing NZ it is predictable – perhaps unlike drought death!

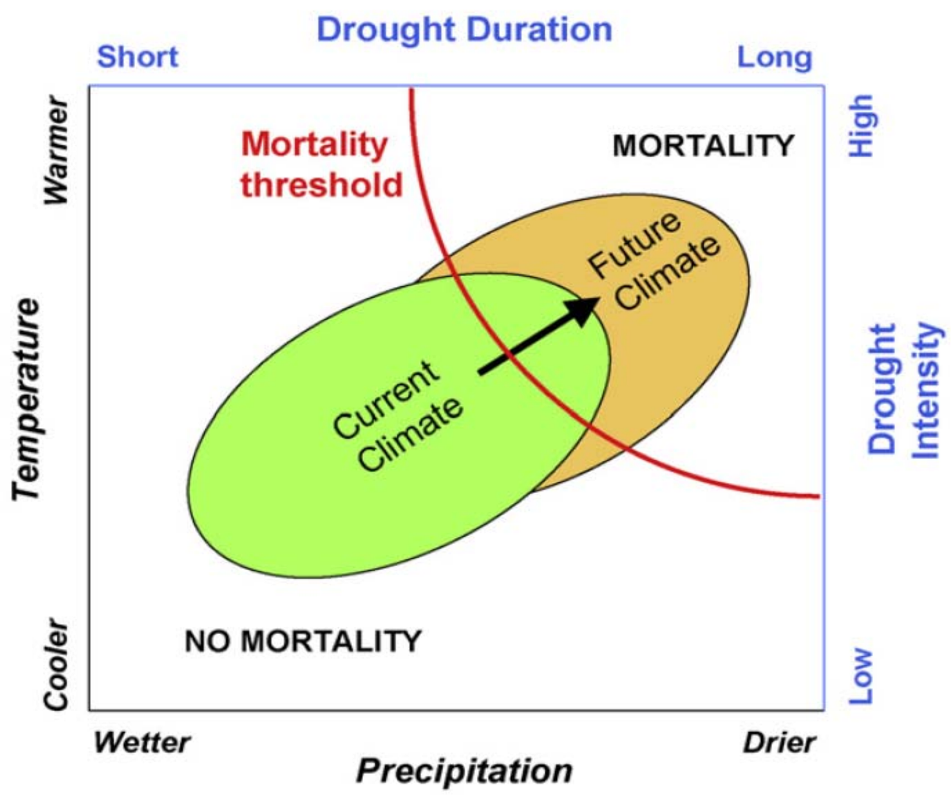
McDowell et al. Trends in Ecology and Evolution October 2011, Vol. 26, No. 10

Where too then?

- We want to be data driven and respect this evidence
- We want to be predictive in complex situations
- We want a framework that leads to action and not just scaremongering
- Adams (2013) following Hawkes (2000) argue for process-based representation of drought to overcome problems. Polari (2014) argues further for statistical-dynamical modelling

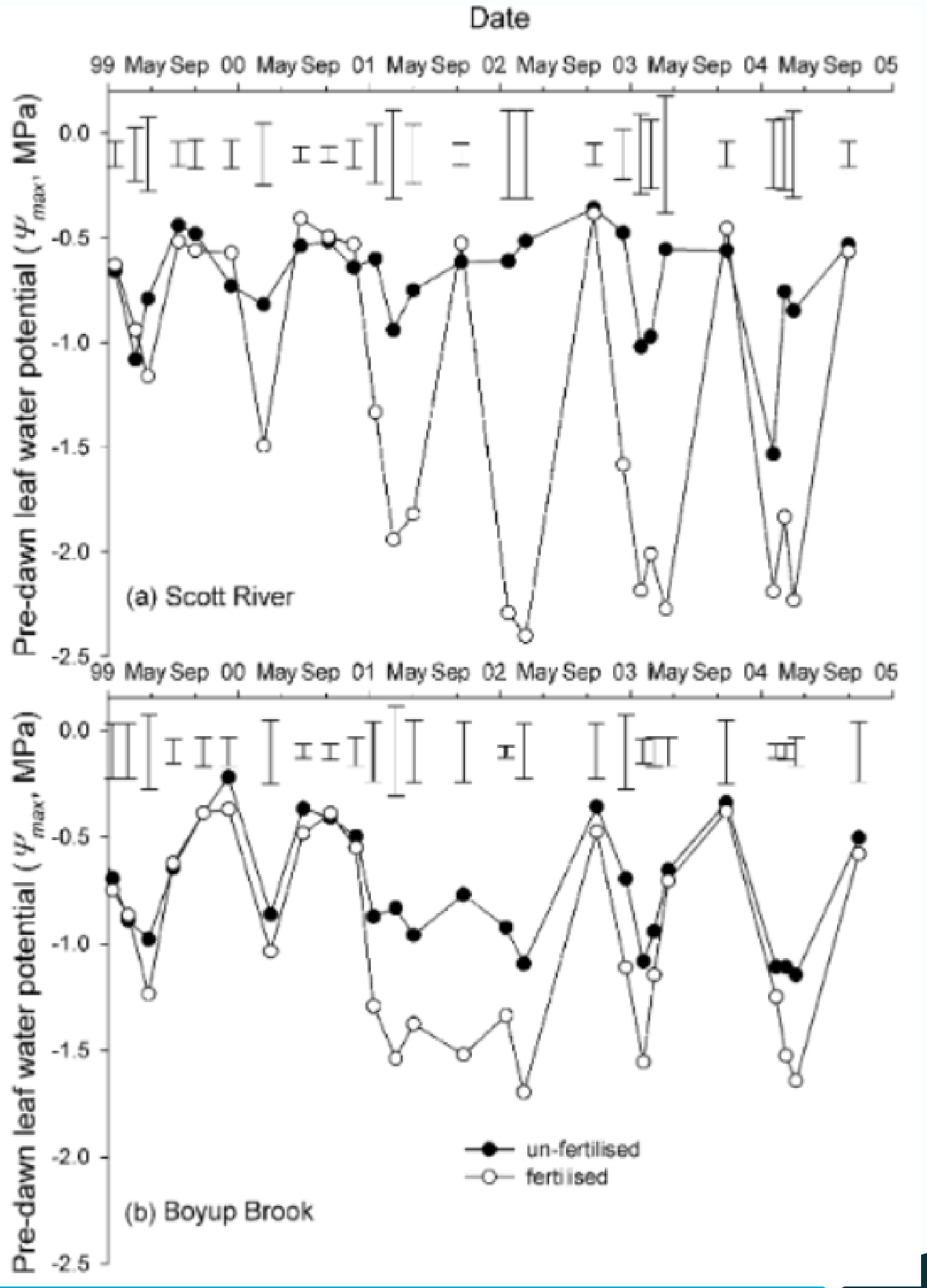
Consistent with our evidence Allen(2010) said forest drought mortality was a function of duration and intensity of drought

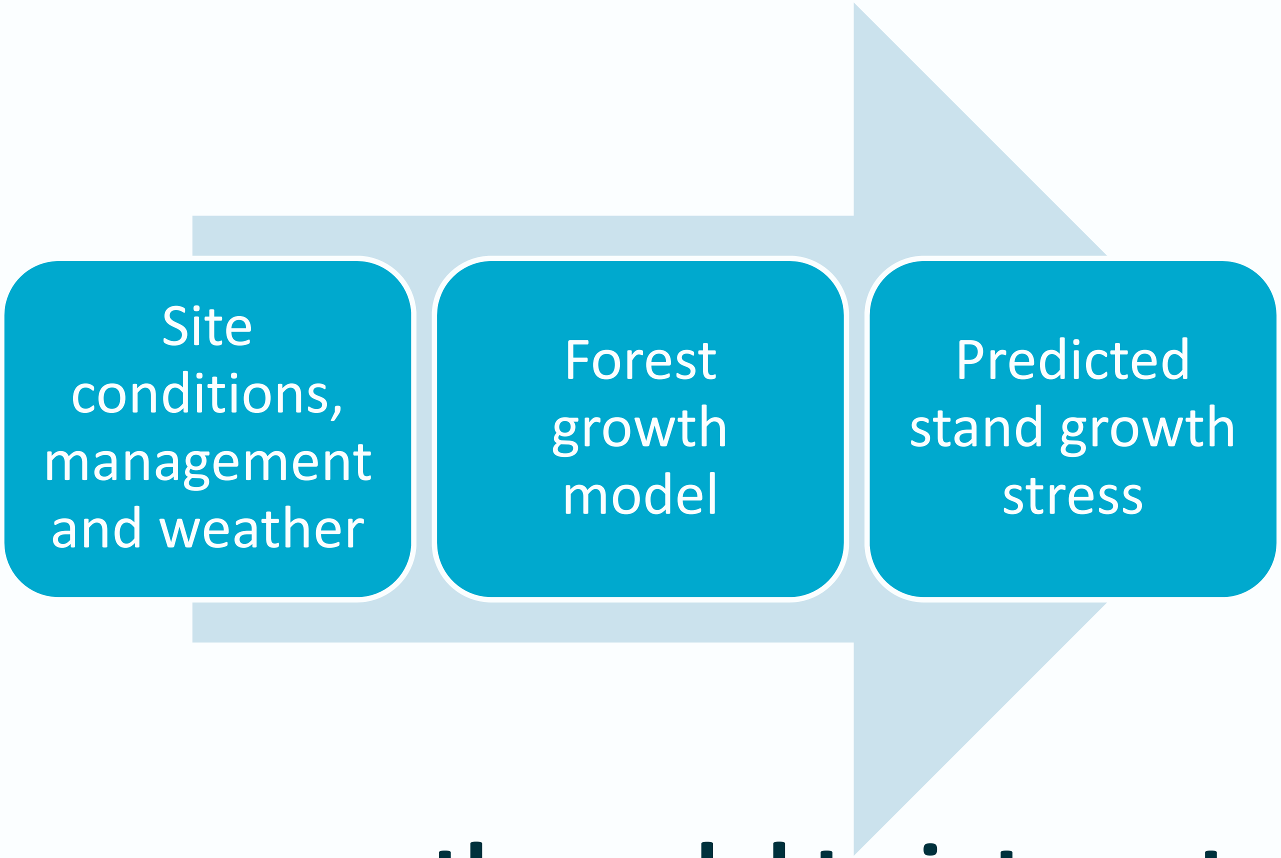
Phenomenological in that doesn't invoke the mechanism



But drought intensity has to be defined by the tree or forest, not the climate

trees and our silviculture intermediates between climate and production

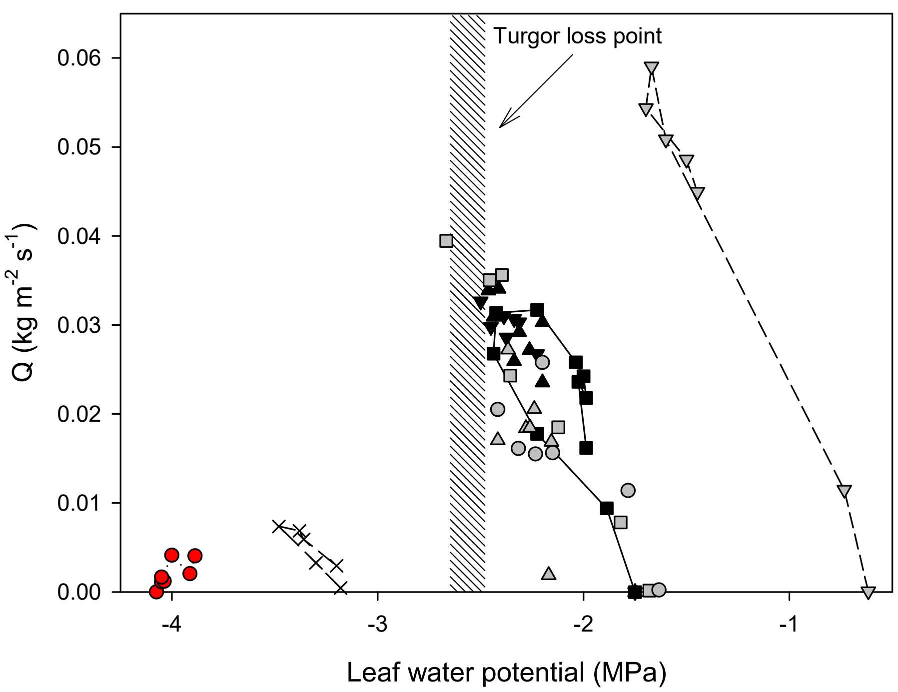




We use a growth model to integrate factors to get a tree water stress – adjusted for local conditions and stand and tree state

Respecting the evidence of physiological thresholds we create a stress dose that looks at duration and intensity in a species specific way

φ_{lethal} φ_T



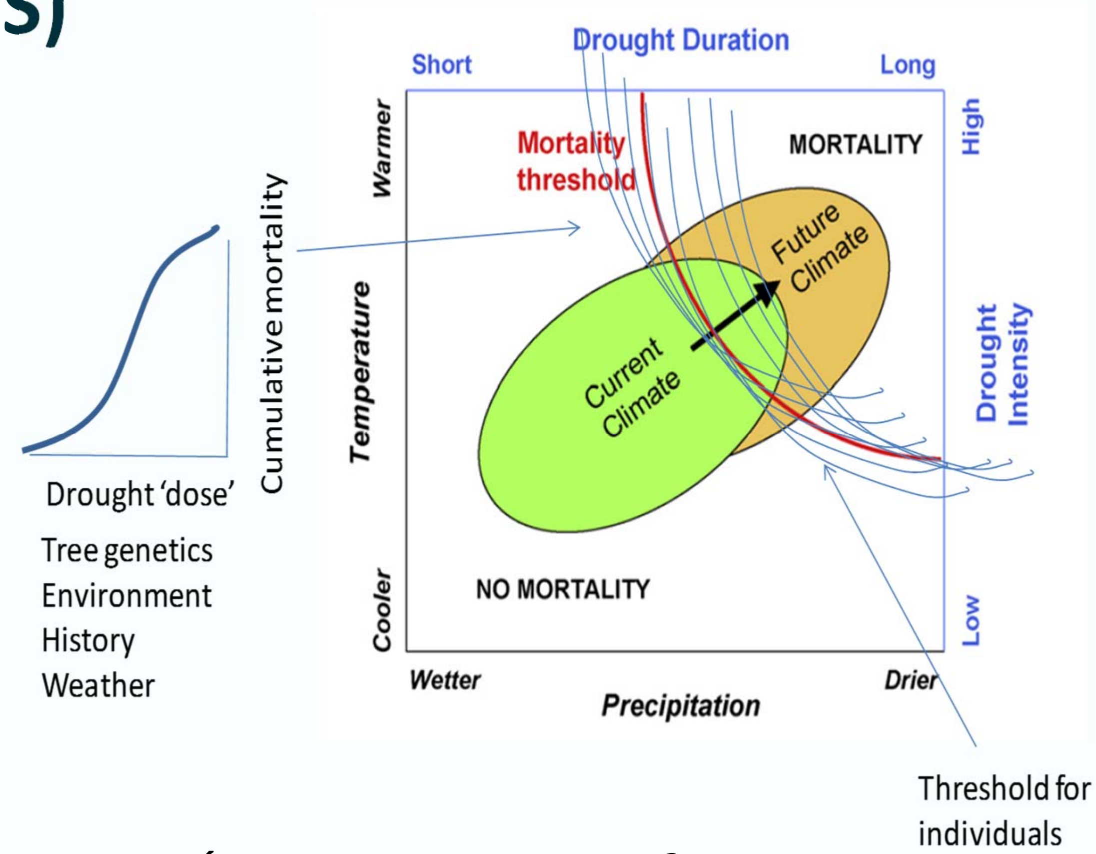
Daily dose (damage) is relate to degree of stress below turgor loss point

$$D = \sum max\left\{\frac{\varphi_T - \varphi_{leaf}}{\varphi_T - \varphi_{lethal}}, 0\right\}$$

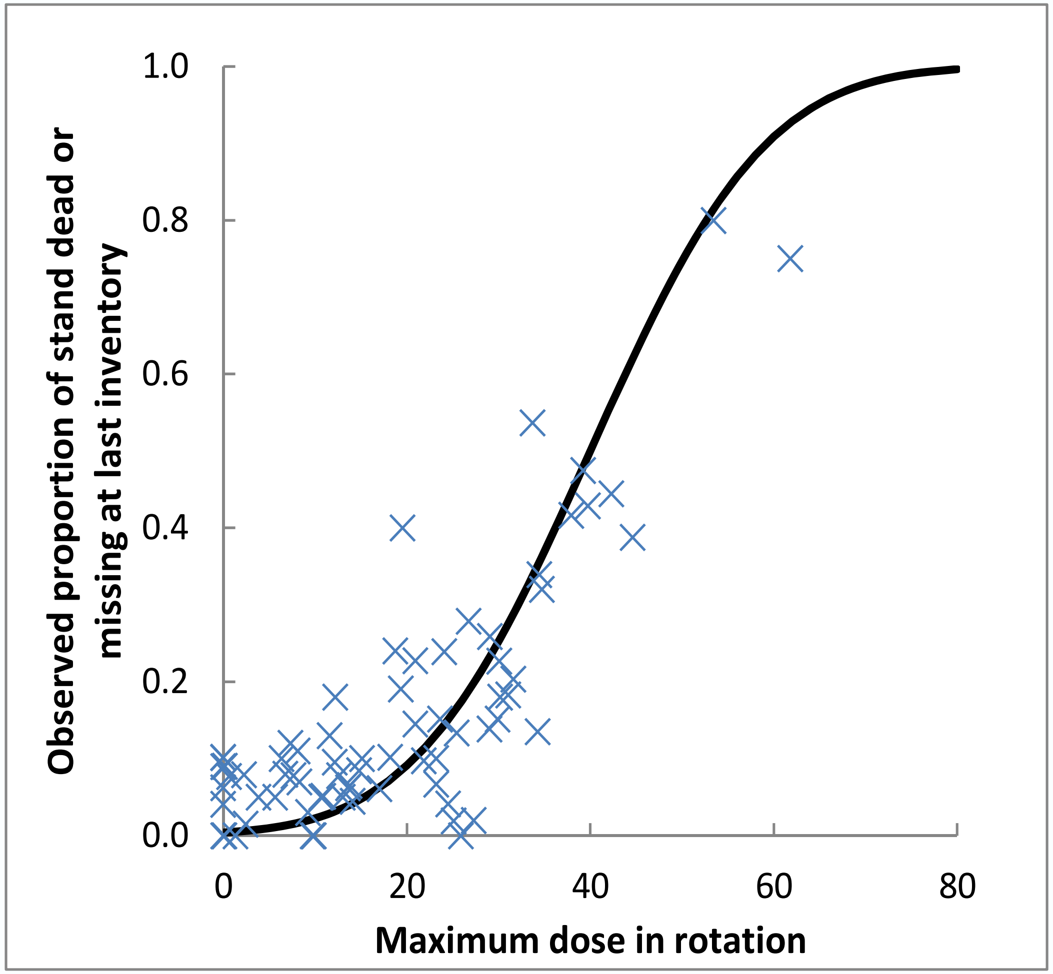
When water stress released recovery

$\sum D=0$, if $\varphi_{leaf} > \varphi_T$

But the evidence tells us there is a (normal) distribution of trees that die at different stress levels (S)



$$\acute{S} = S[1 - N\{SD, D_{50}, \sigma^2\}]$$

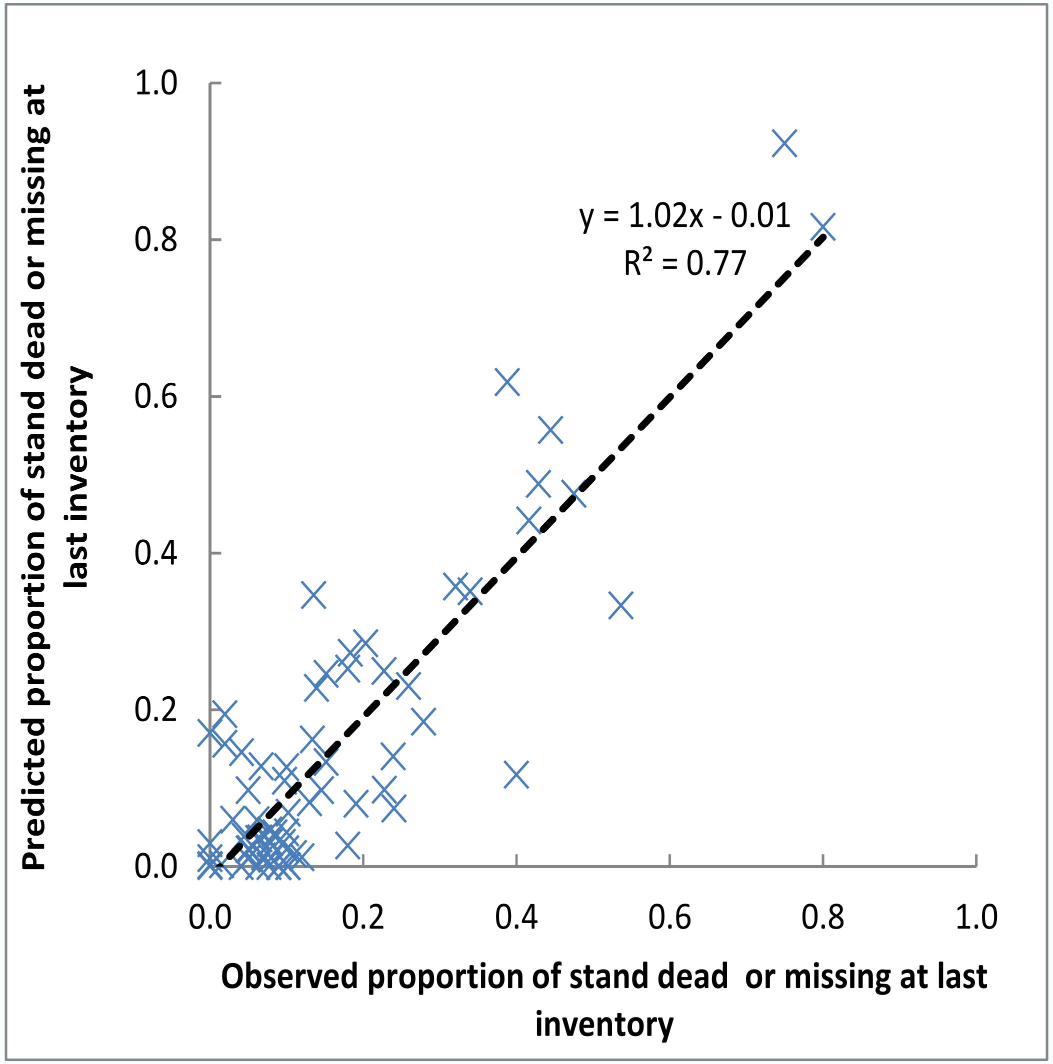


72 Eucalyptus globulus plots in Western and Southern Australia, many paired where site differences across short distances

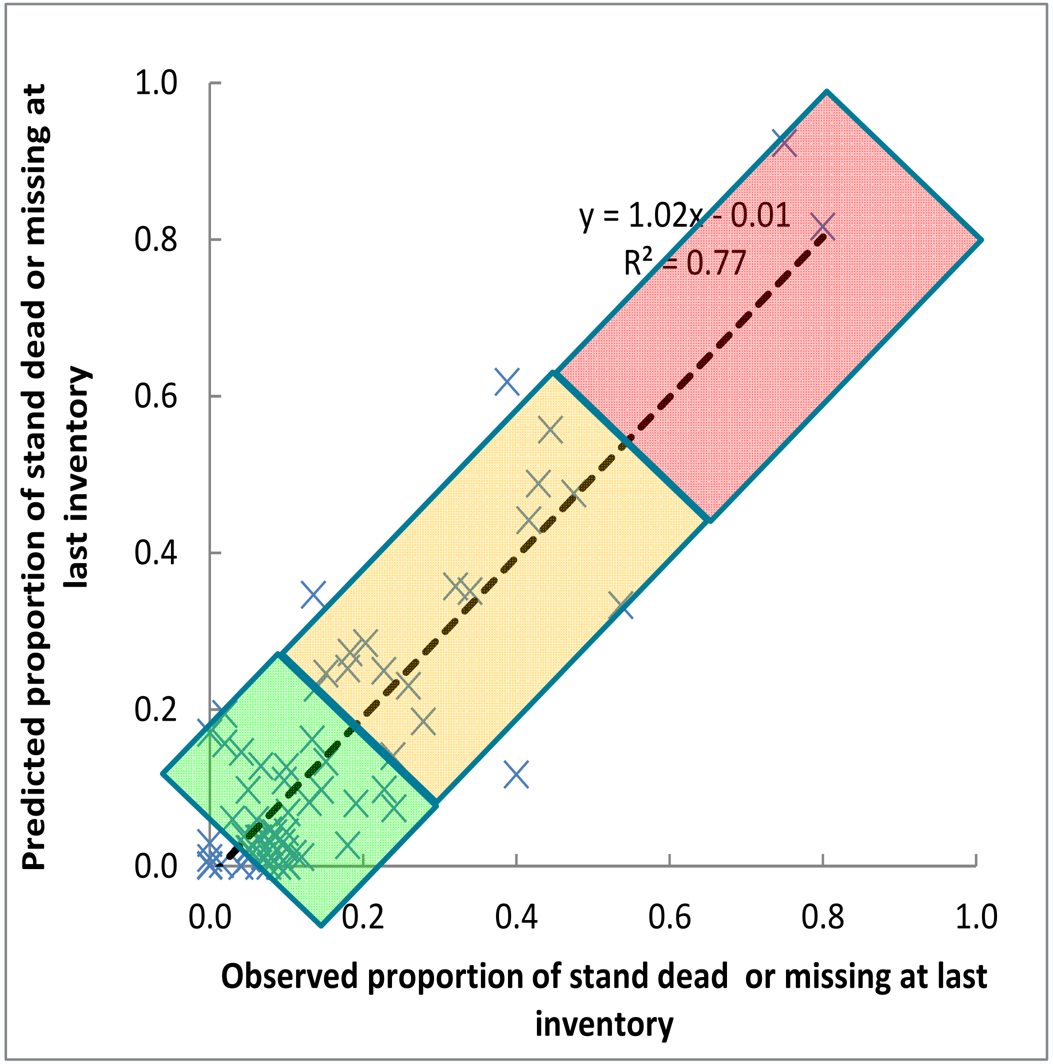
Aged between 4.5 and 22.1

Initial stocking between 743 and 1250 spha

μ=40 and s^2=15



Predicted proportion of stand dead or missing at last inventory
1.0
0.8
0.6
0.4
0.2
0.0
y = 1.02x - 0.01
R² = 0.77
0.0
0.2
0.4
0.6
0.8
1.0
Observed proportion of stand dead or missing at last inventory



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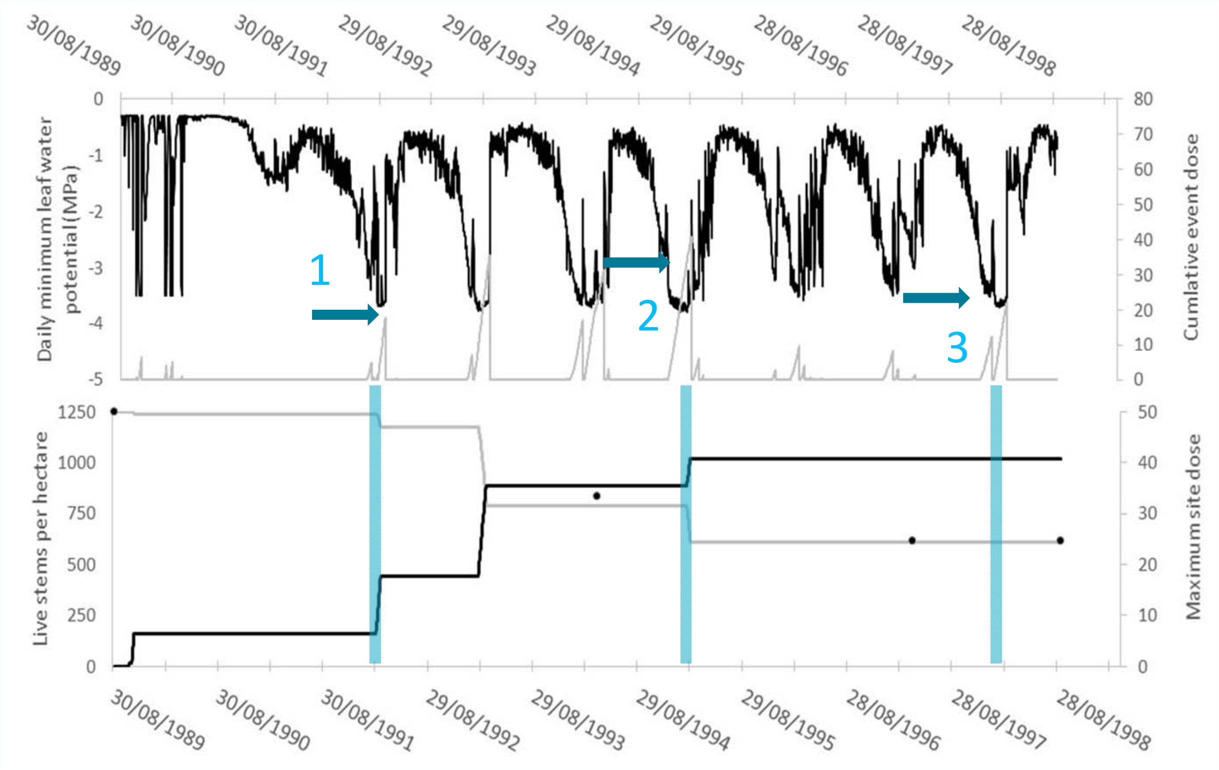
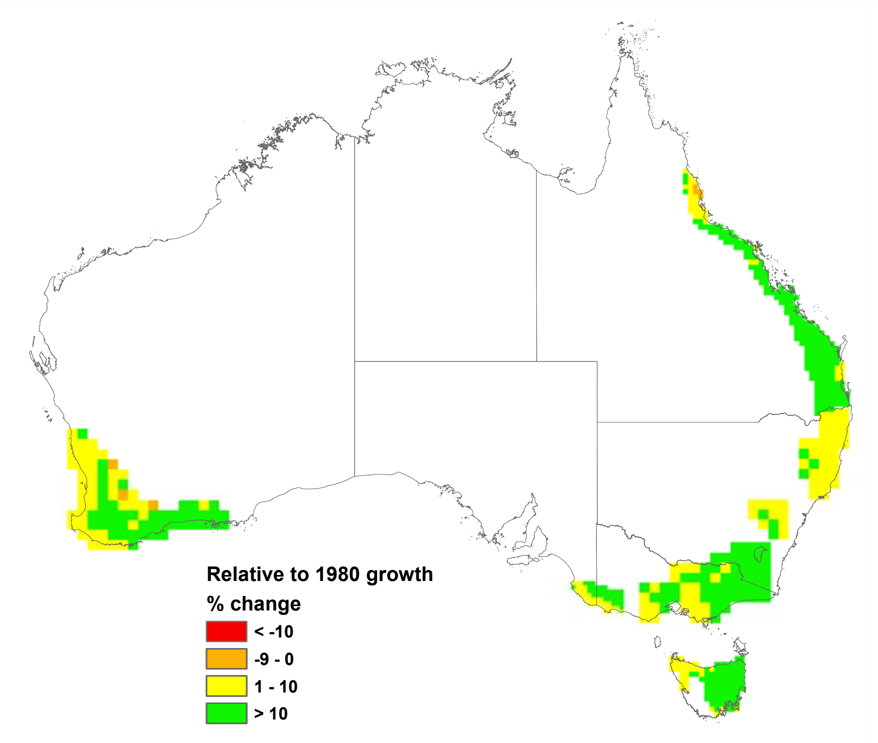
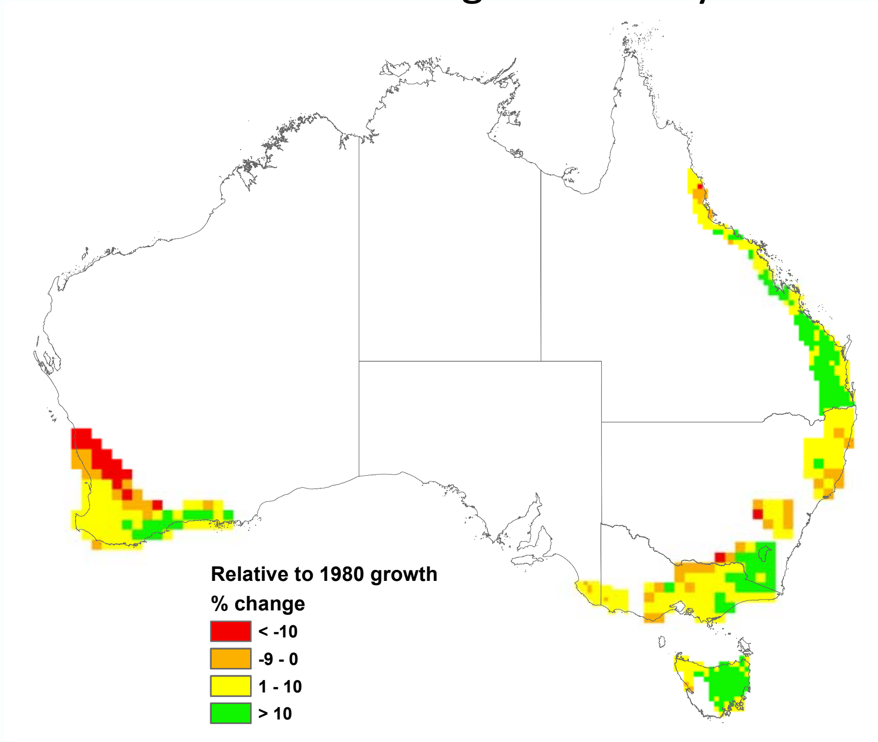
A. Plot 27



- Time course from date of planting to last inventory of daily leaf water potential (black line top pane), model drought stress dose (grey line top pane), and observed (dots) and predicted live stems per hectare (grey line bottom pane) and maximum site dose value to that point in time (bottom pane black line.

Add in drought mortality



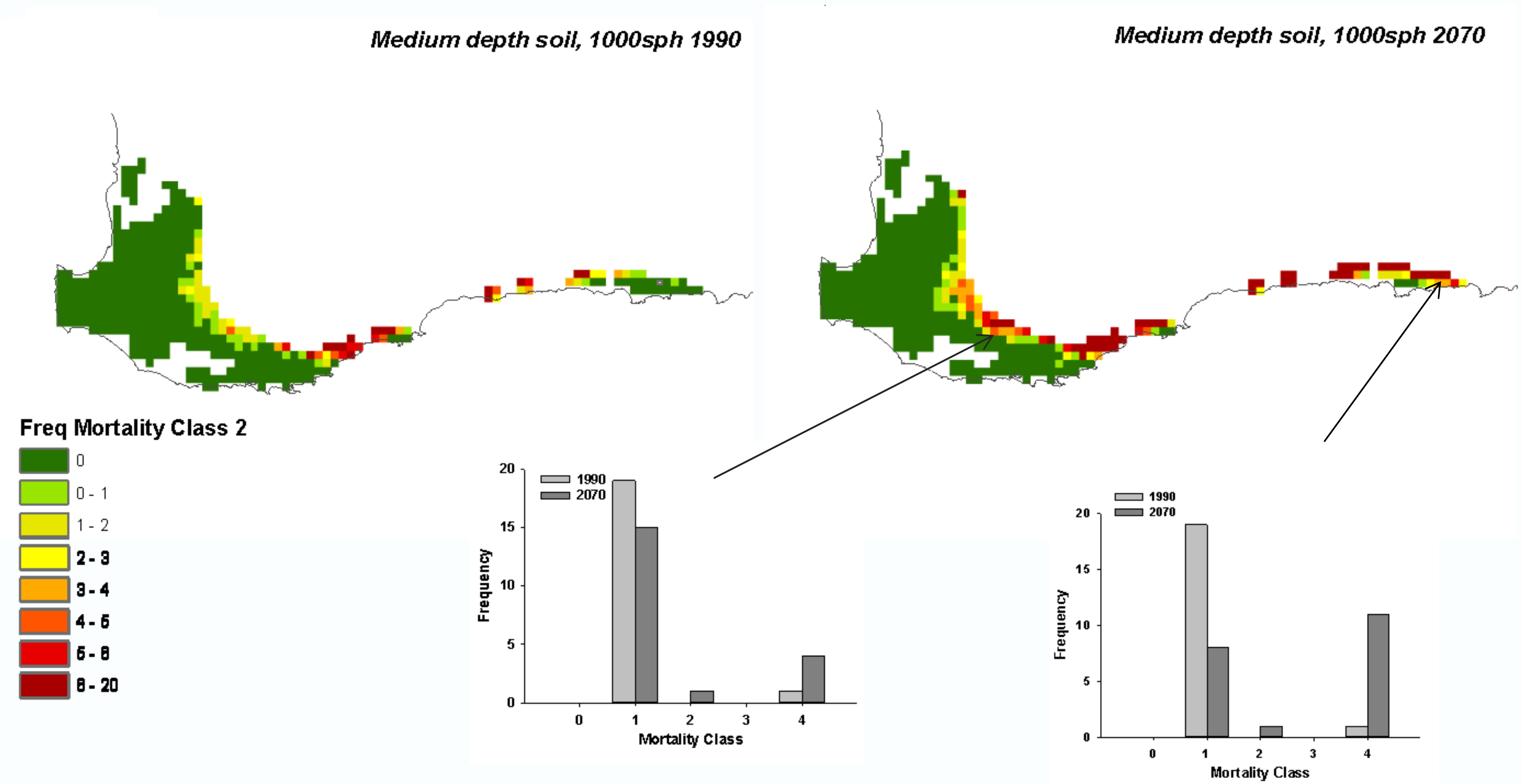


Battaglia et al 2009

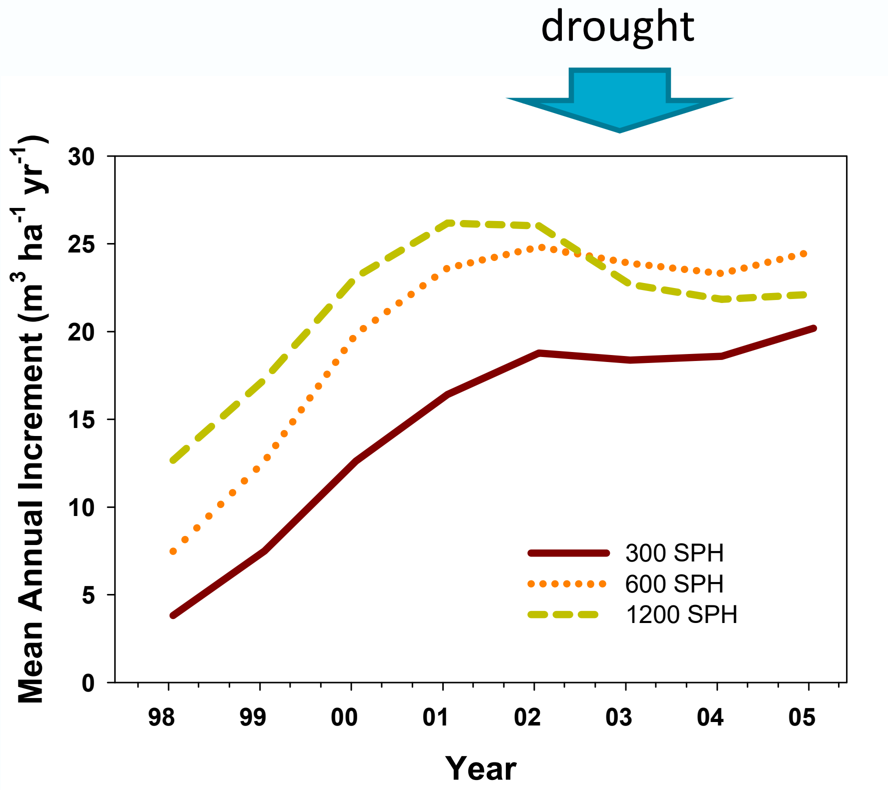
Effect	Net change
No Mortality	+12.8%
With Mortality	-7.3%

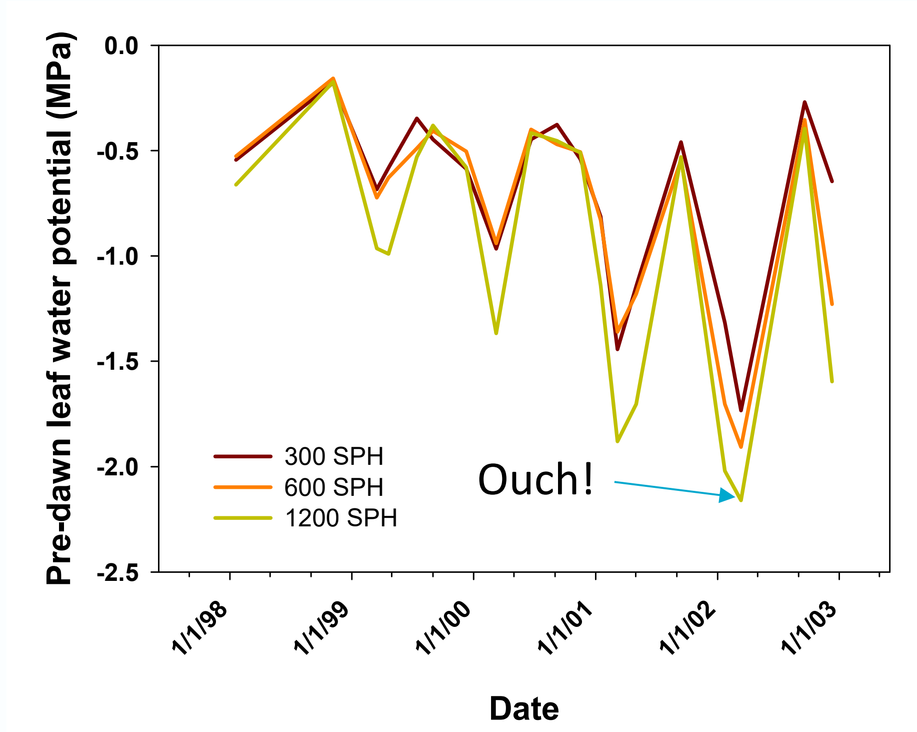
Number of rotations out of 20 where there is a moderate or severe risk of drought death (≥class 2) on 5m deep soils

White et al 2011 Climate driven mortality in forest plantations – prediction and effective adaptation



Evidence again: But we have some control



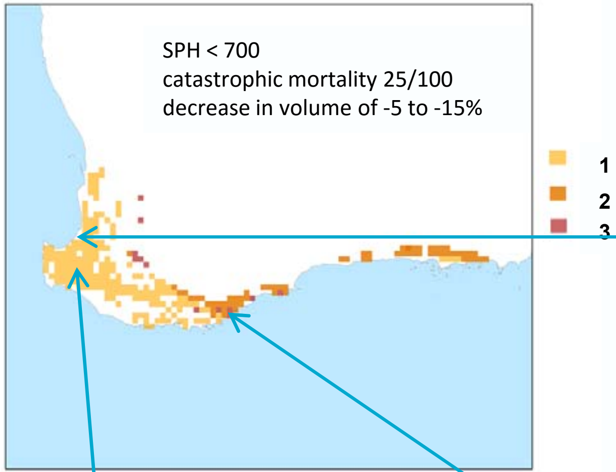


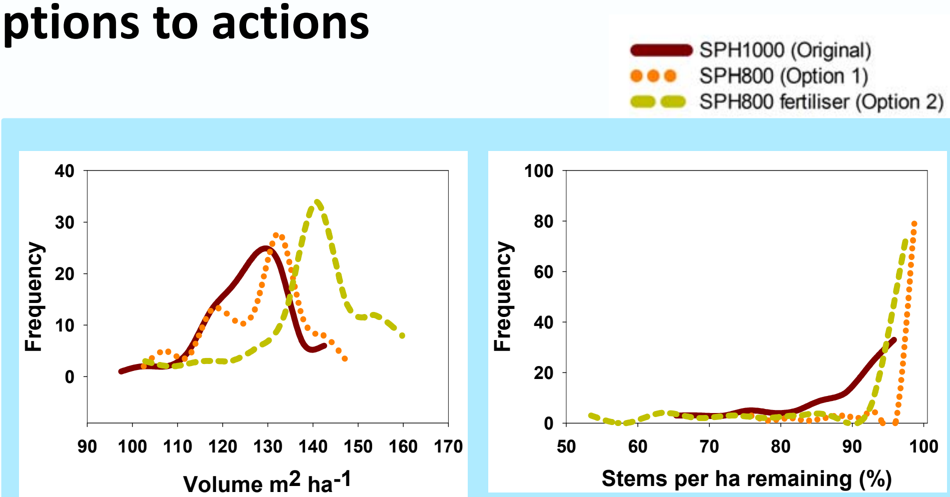
White DA, Crombie DS, Kinal J, Battaglia M, McGrath JF, Mendharn DS, Walker SN (2009) Managing productivity and drought risk in Eucalyptus globulus plantations in south-western Australia. *Forest Ecology and Management* **259**, 33-44.

White et al. 2009 FEM 259, 33-44

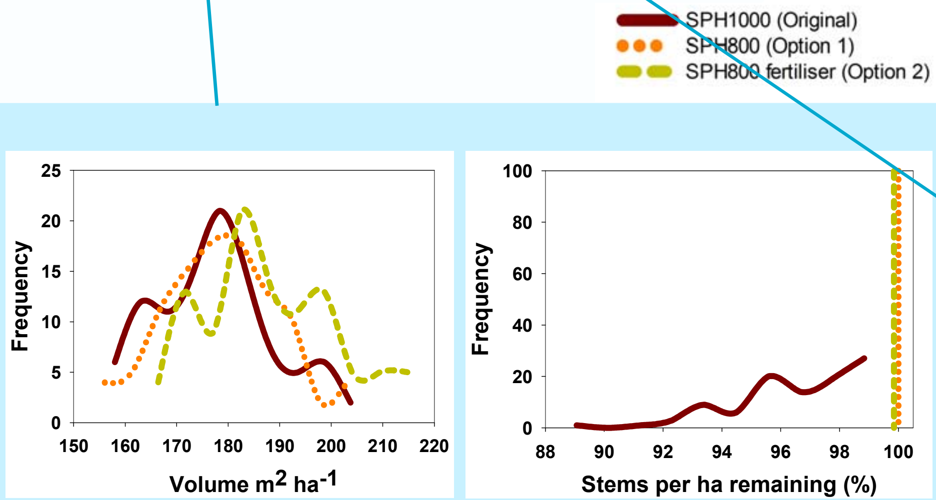
Adaptation to changes in production mortality: moving from descriptions to actions

Risk

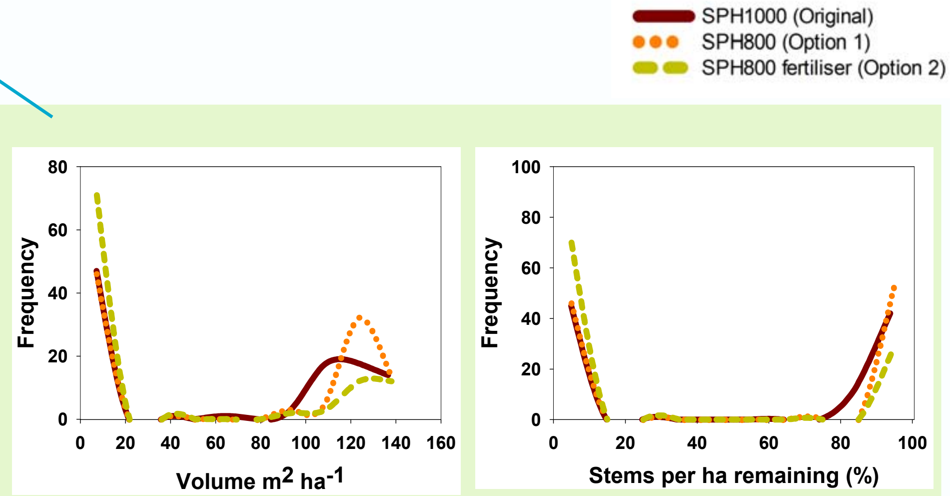




Effects of changes in stocking and fertiliser application on production and mortality



Effects of changes in stocking and fertiliser application on production and mortality



Effects of changes in stocking and fertiliser application on production and mortality

Conclusions

- We have framed precision forestry as data driven decision making
- In some areas in which we want to make decisions our data is sparse, and uncertainty is high
- We can ‘amplify’ the power of our data, and overcome the tyranny of the unique observation, by fitting them into a conceptual framework and modelling
- We should respect the science – modelling is a creative exercise, modelling ignoring the facts is a delusional exercise
- To support adaptation we need to move from the science to identification of hazard to the presentation of loss in appropriate (actionable) manner
- Information (modelling) needs to be decision-centric and locally relevant

Thank you

Michael Battaglia
Group Leader

t +61 3 62 375612
e michael.battaglia@csiro.au
w www.csiro.au