Climate change impacts on stand production and survival, and adaptation strategies to build resilience

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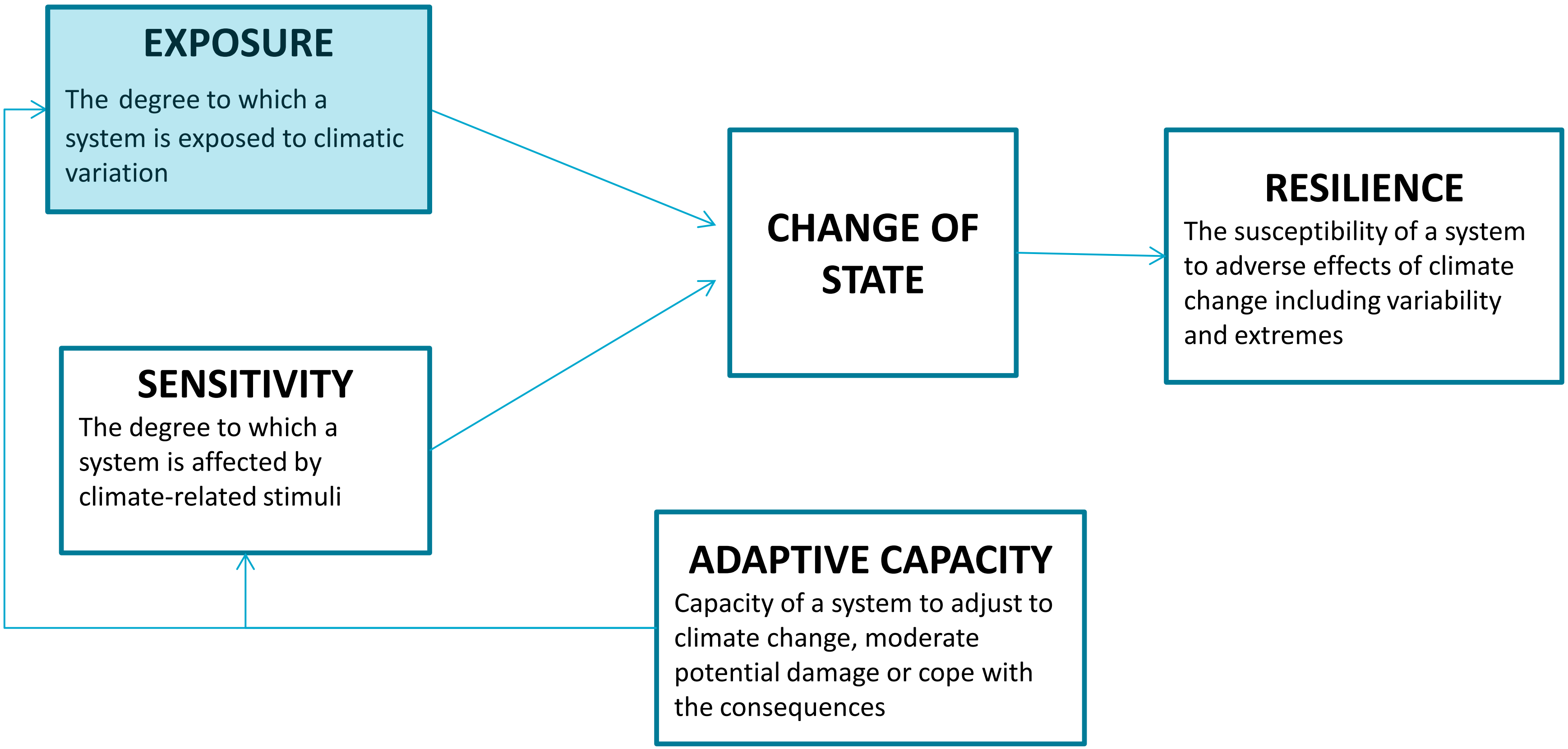
Potential impact

Exposure – climate models downscaled to 10km



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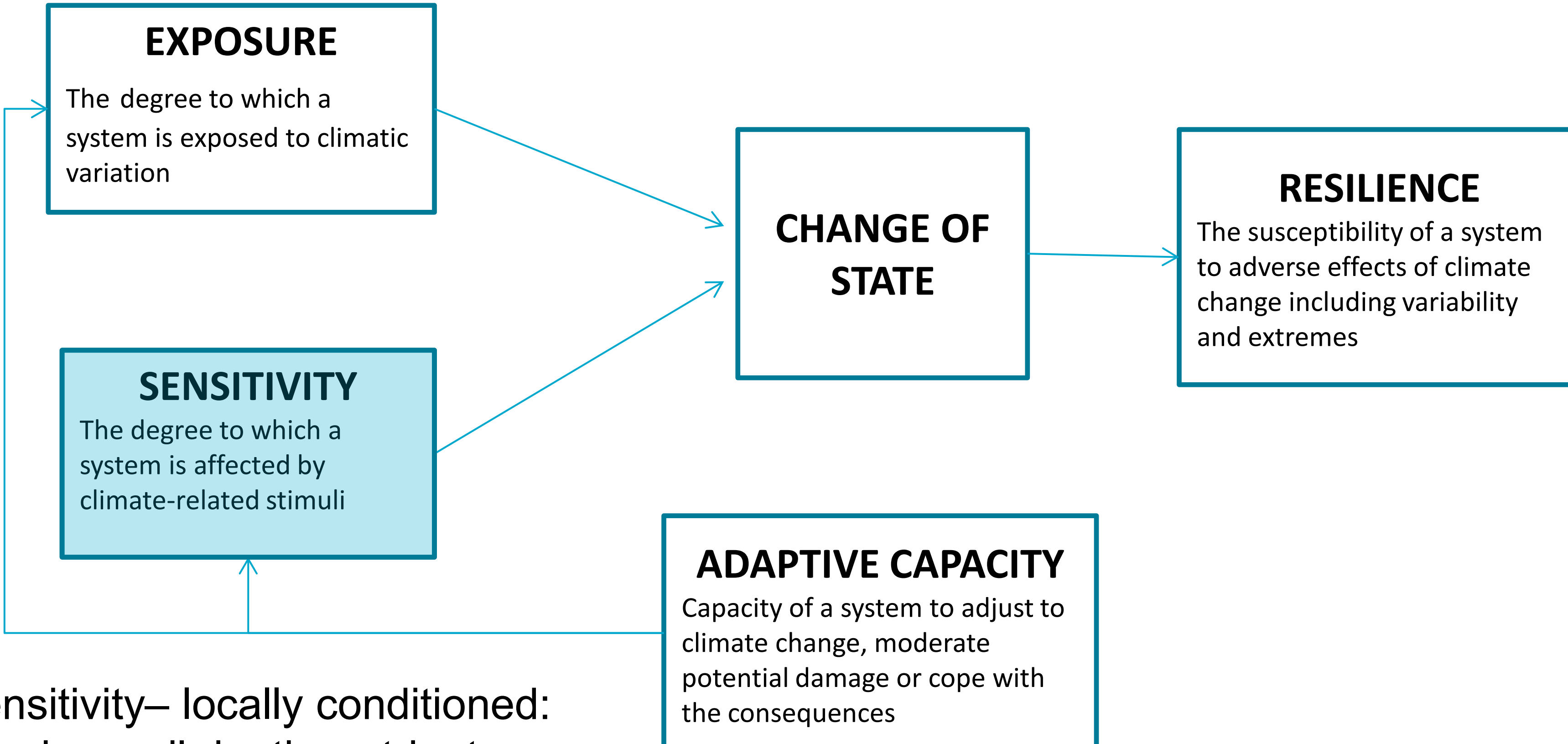
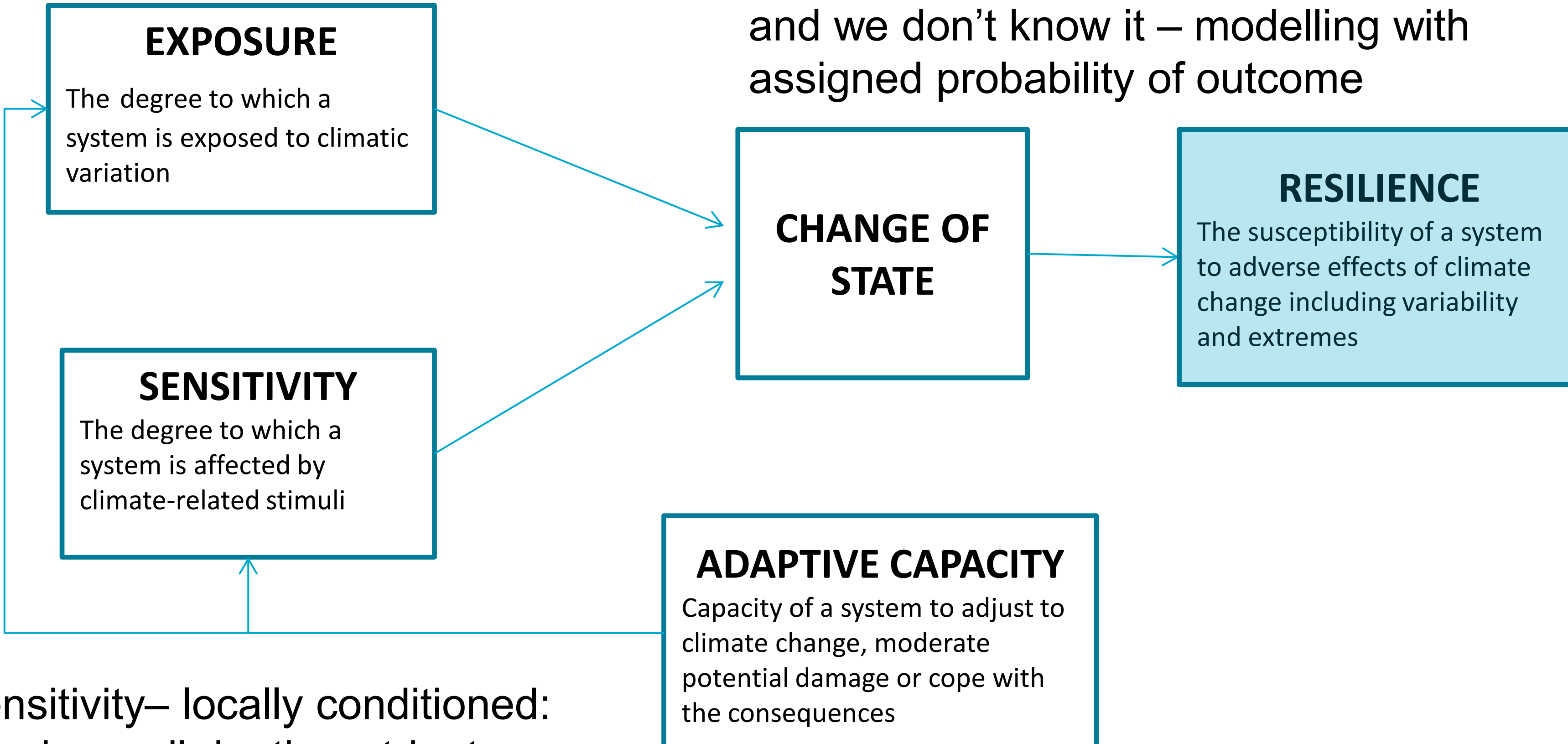


Sensitivity– locally conditioned: species, soil depth, nutrients, age ... Management history

Potential impact

Exposure – climate models downscaled to 10km

Changed state – this is in the future and we don't know it – modelling with assigned probability of outcome



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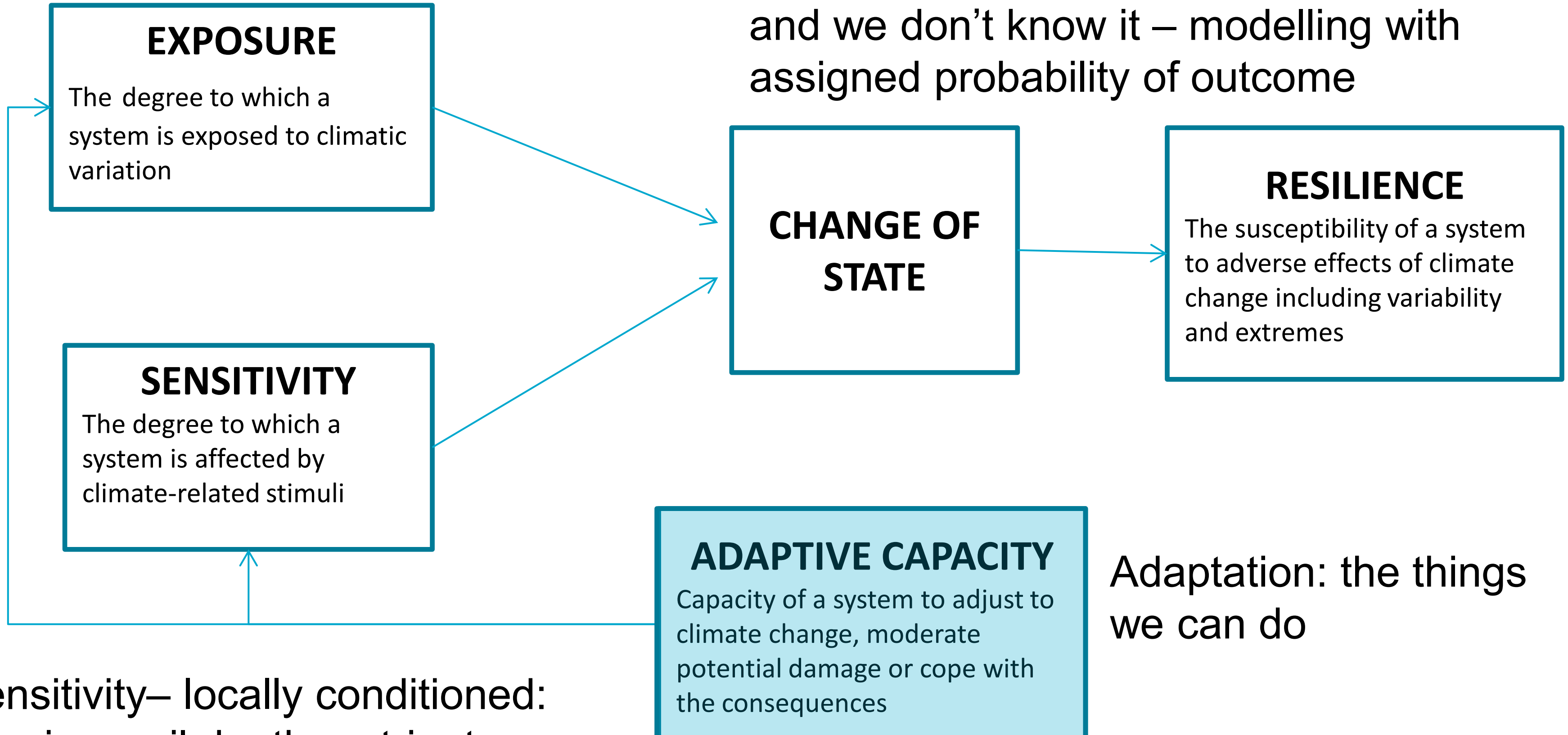


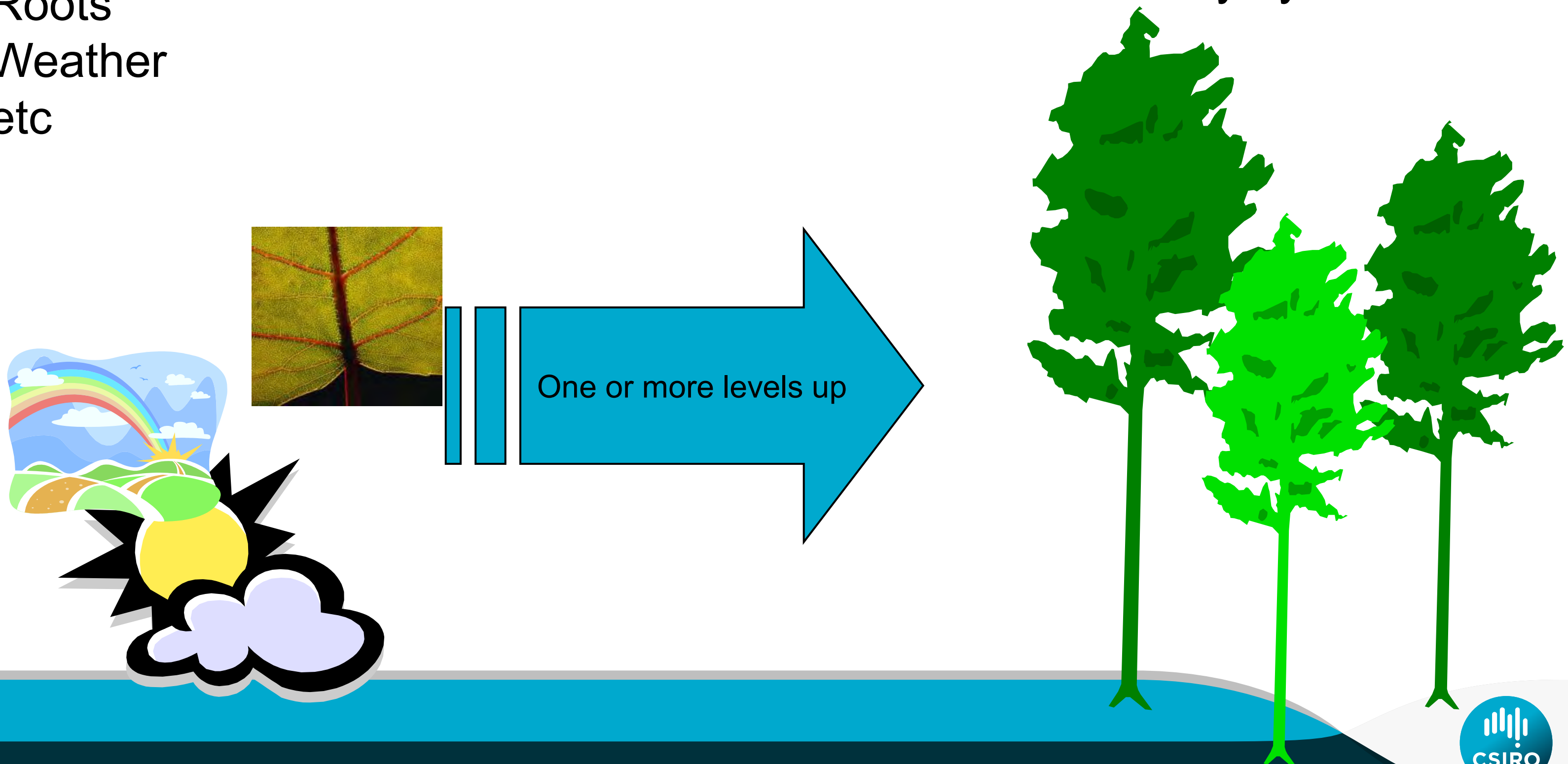
Adaptation: the things we can do

Sensitivity– locally conditioned: species, soil depth, nutrients, age ... Management history

What is a process-based model?

Input level
- Soil
- Photosynthesis
- Leaves
- Roots
- Weather
- etc

Output level
- Forest products
- CAI
- hectares
- days-years

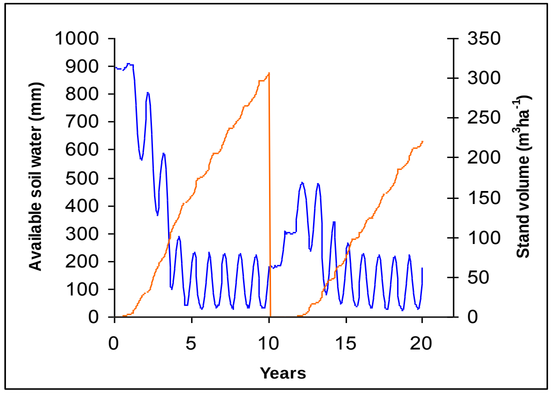


Under what situations is CABALA designed to work?

Single species stands and belts

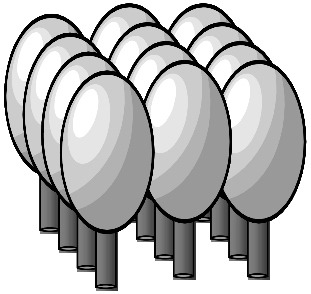
'Simple' soils, only N limitation

Silvicultural interventions, weed understory and pests

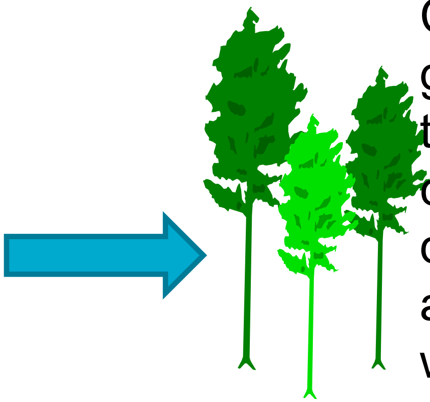


Multiple rotations but generally only 50-100 years per rotation

Coppice stands



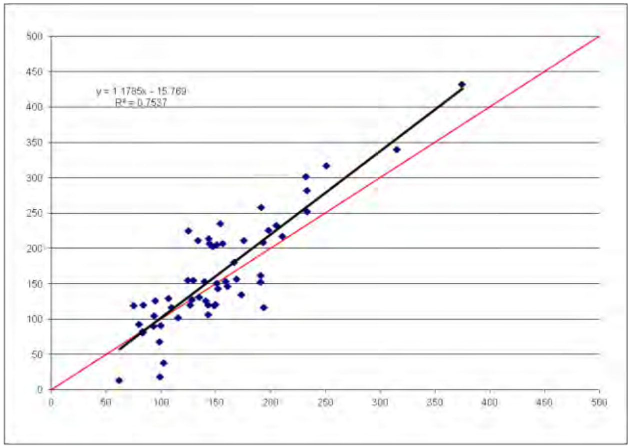
Happy to deal with 'average trees'



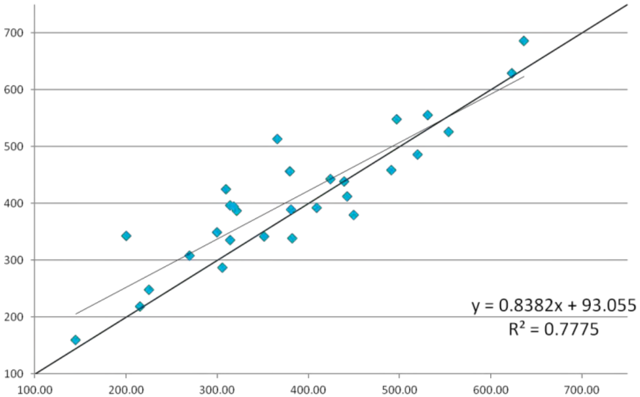
Can generate tree size class distributions, and link to wood quality models

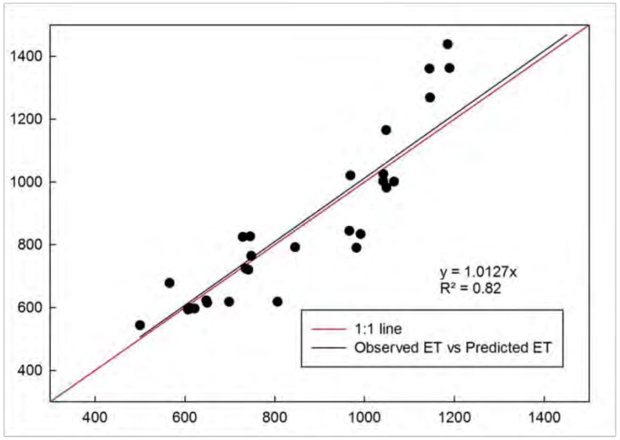
CABALA validation

Eucalyptus globulus



Pinus radiata

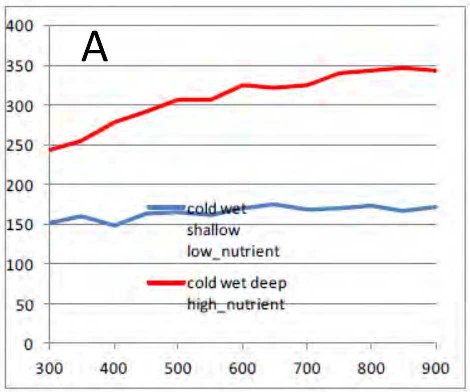


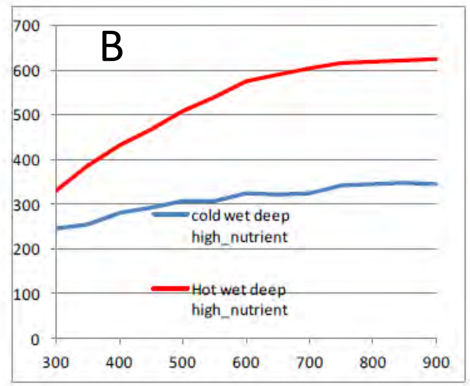


Evapotranspiration =Tree transpiration + soil evaporation + canopy interception

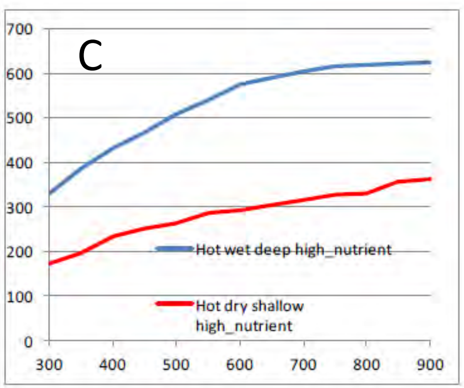
Response to eCO_2

Stand volume, m3/ha





Atmospheric CO_2 partial pressure, ppm



Atmospheric CO_2 partial pressure, ppm

Some examples of the predicted volume response of *E. globulus* to increasing atmospheric CO_2 concentrations:

(A) cold wet site with either shallow nutrient poor soil or deep nutrient rich soil;
(B) cold wet or hot wet site with deep nutrient rich soils;
(C) hot wet site with deep nutrient rich soil or hot dry site with shallow nutrient rich soil.

Sites	Av annual Rainfall (mm)	Av max Temperature (°C)	Av min Temperature (°C)
Cold dry	588	17.3	7.8
Cold wet	1342	14.0	5.8
Hot dry	810	22.6	9.2
Hot wet	1147	20.7	10.9

CSIRO

Sensitivity analysis

Soils

Region	High Fertility OM% and C:N ratio () top 10cm	Medium fertility OM% and C:N ratio () top 10cm	Low fertility OM% and C:N ratio () top 10cm	Shallow soil depth (m)	Deep soil depth (m)
Northern NSW	4.2 (15)	2.5 (22)	1.3 (30)	0.8	3
SA/GT	4 (18)	2 (30)	1.2 (38)	2.5	6
SW WA	4 (18)	3 (22)	1.5 (28)	5	9
Tasmania	7 (15)	2.5 (20)	1.3 (28)	0.8	2.5
Vic and Southern NSW	5 (15)	2.5 (22)	1.2 (28)	0.8	3

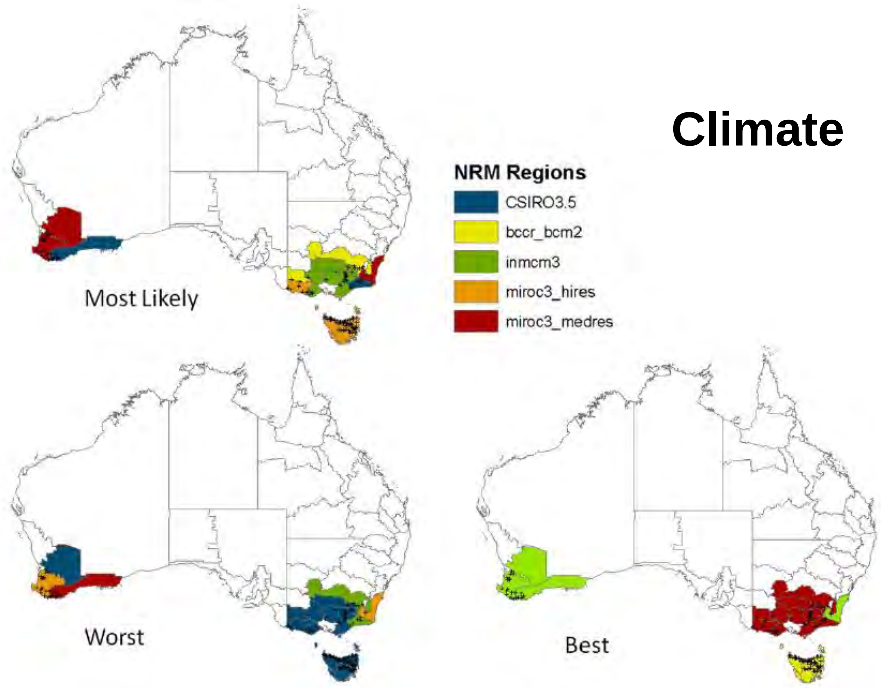
Management

- The silvicultural regime used for *E. globulus* was a 10 year rotation planted at 1000 stems per hectare

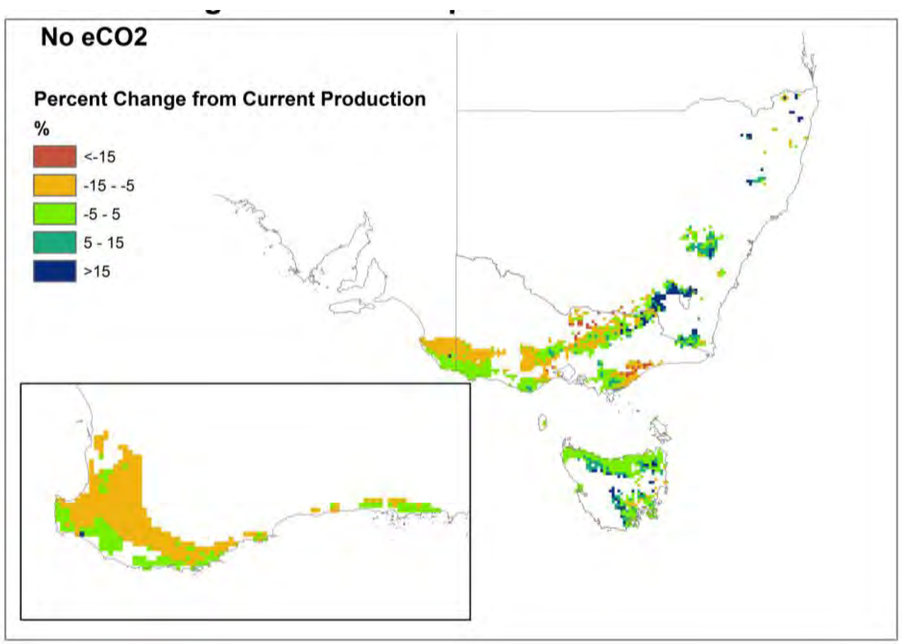
- For *P. radiata*, planting was at 1333 sph, with a rotation length of 35 years, and three commercial thinning events. The first thinning was at age 11 with the reduction to 750 sph,
the second at age 19 years to 450 sph and the final thinning at age 26 years to 250 sph.

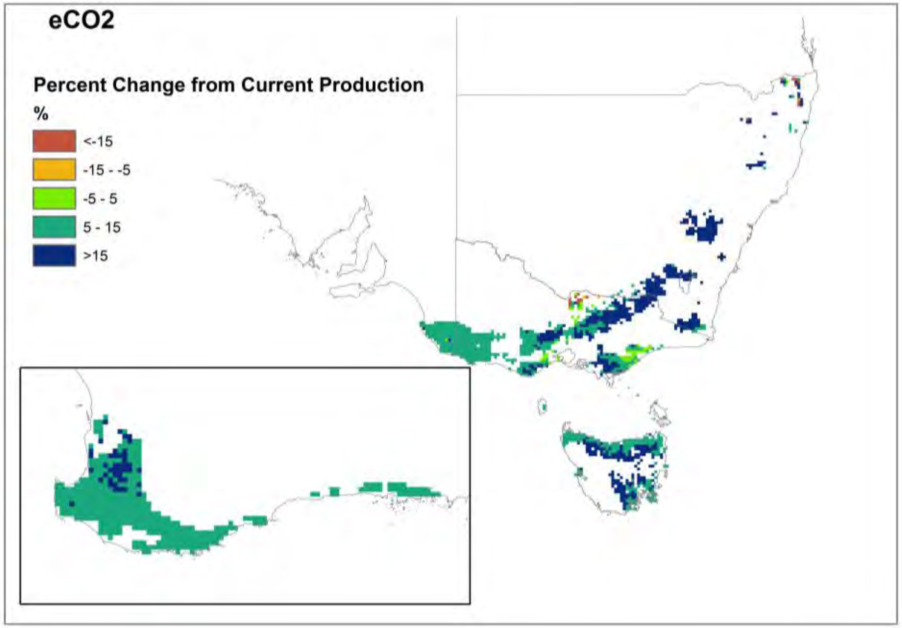
With and without eCO_2

Climate



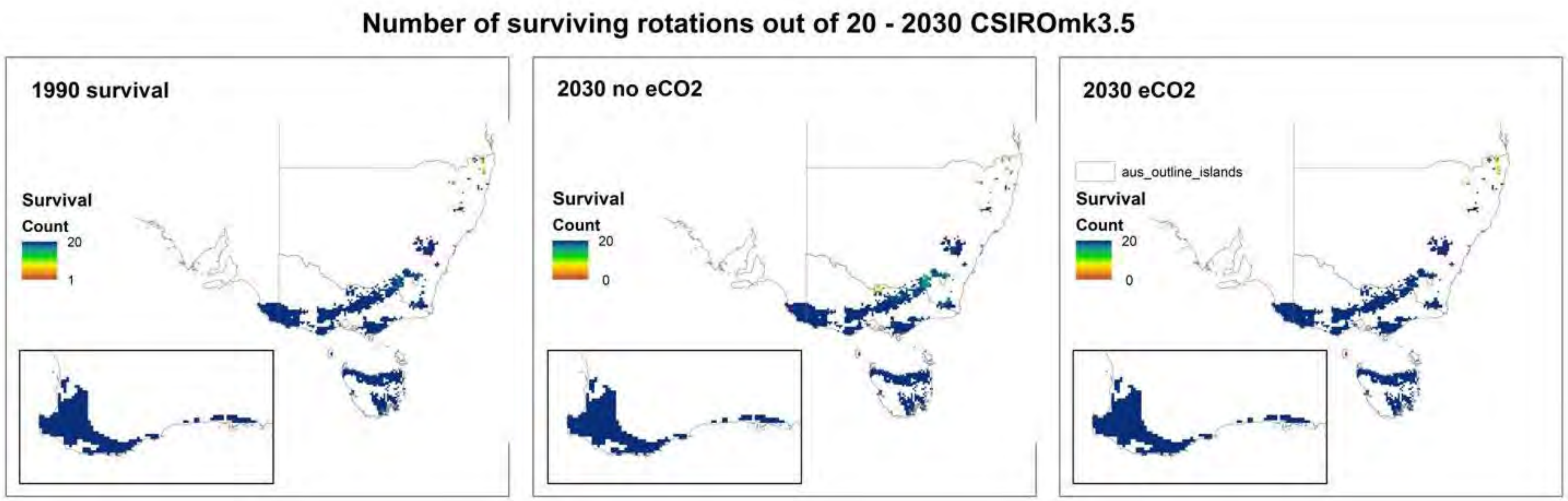
Change in production from current production 2030 CSIROMK3.5 for *Pinus radiata*





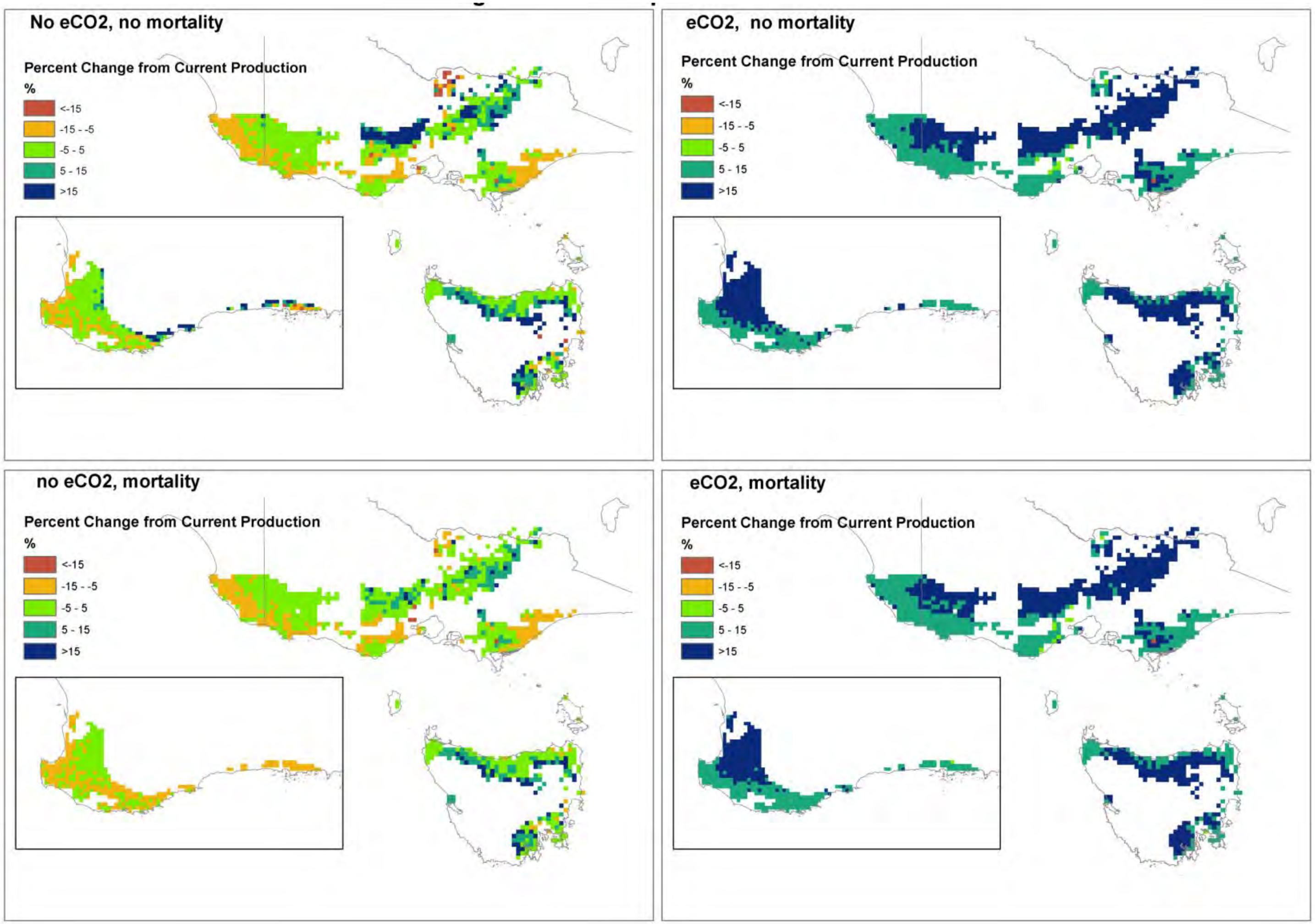
Percentage change in total volume of *P. radiata* in 2030 and 2050 compared with 1990 total volumes under assumption of eCO_2 and no eCO_2 response**.** The climate model is the CSIRO MK3.5 GCM and the soils are medium fertility, deep soils.

Number of surviving rotations out 20 for *Pinus radiata*



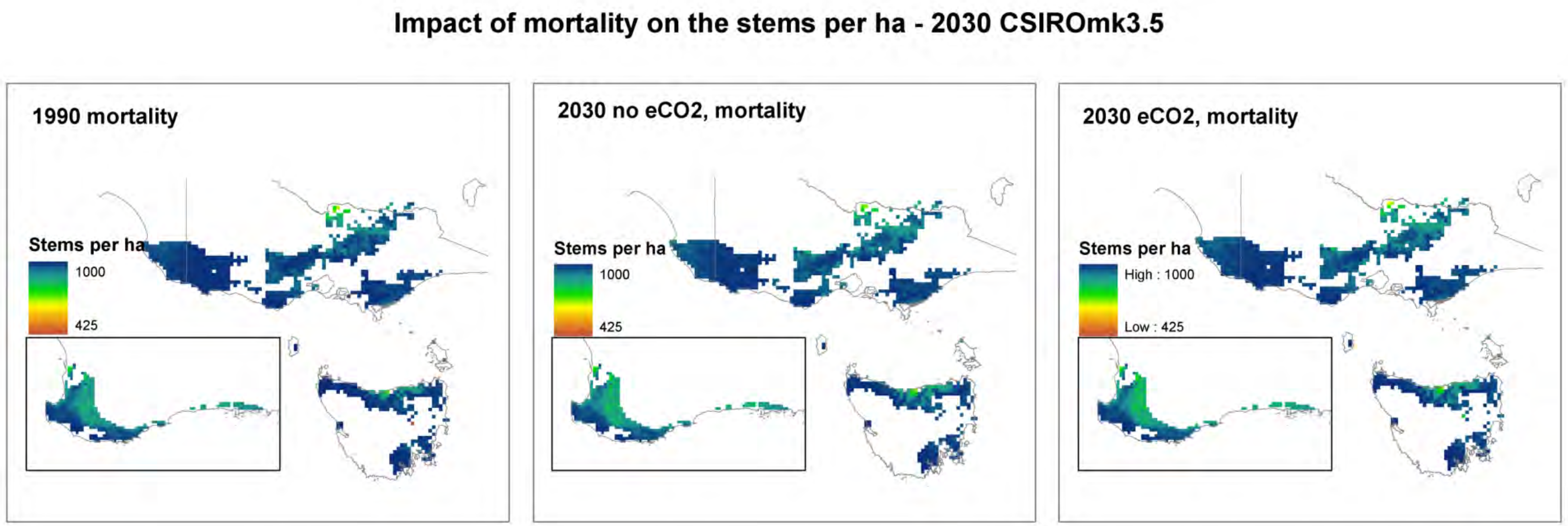
The survival of *Pinus radiata* plantations under 1990 and 2030 climate change conditions with and without eCO_2. Survival refers to the number of rotations that survived out of 20. The climate model is the CSIRO MK3.5 GCM and the soils are medium fertility, deep soils.

Change in production from current production 2030 CSIROMK3.5 for *Eucalyptus globulus*



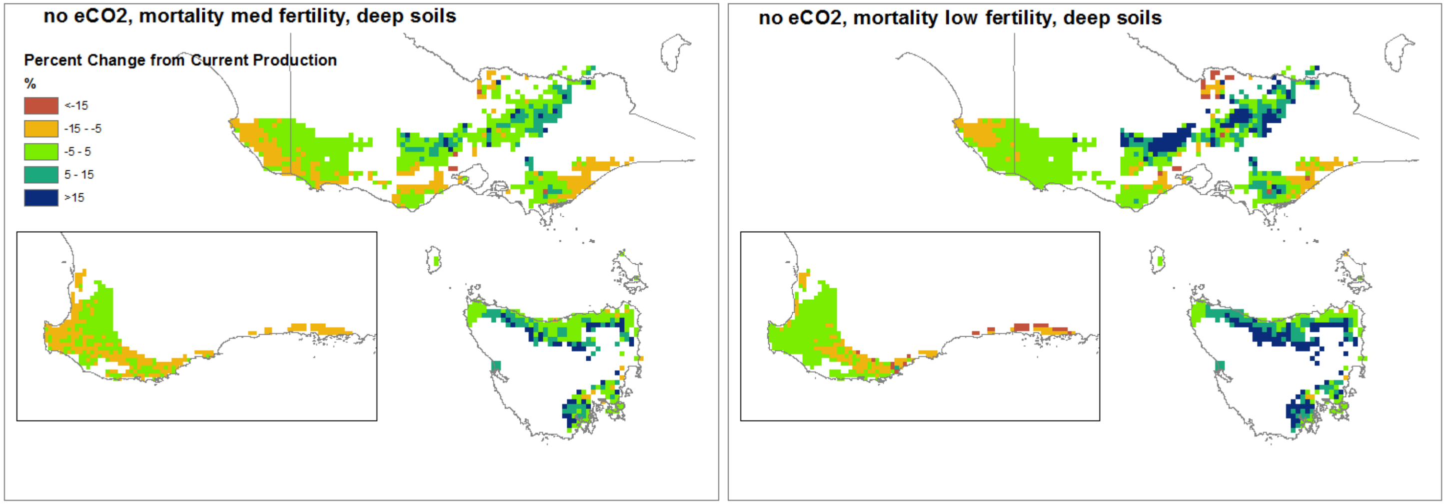
Percent change from current production of *E. globulus* under a range of modelling assumptions
The climate model is the CSIRO MK3.5 GCM and the soils are medium fertility, deep soils.

Predicted mortality within stands for *Eucalyptus globulus*



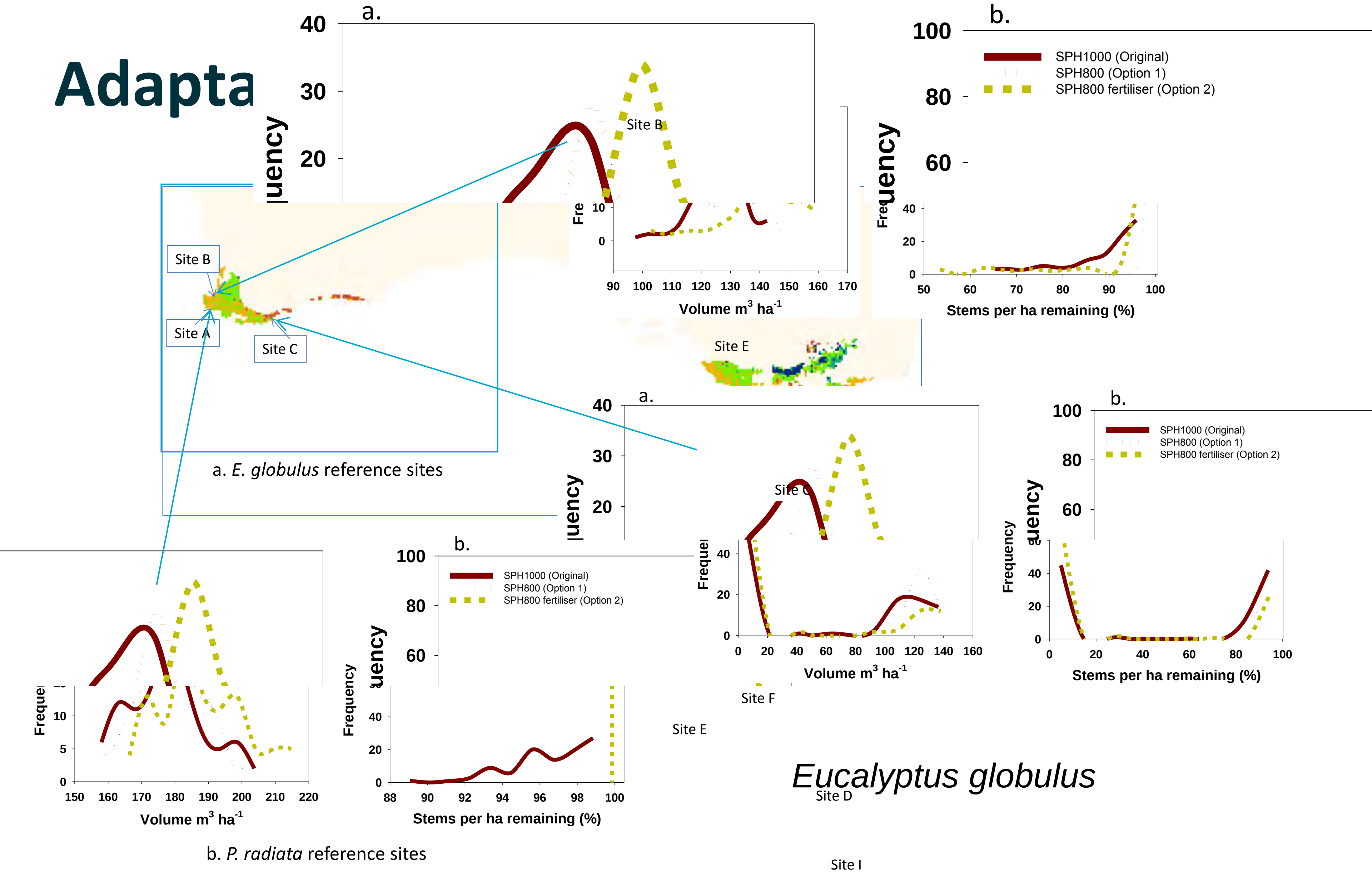
End of rotation survival of *E. globulus* as stems per hectare after initial planting density of 1000 sph in 2030 under ambient and eCO_2 The climate model is the CSIRO MK3.5 GCM and the soils are medium fertility, deep soils

Interaction of fertility and warming temperatures



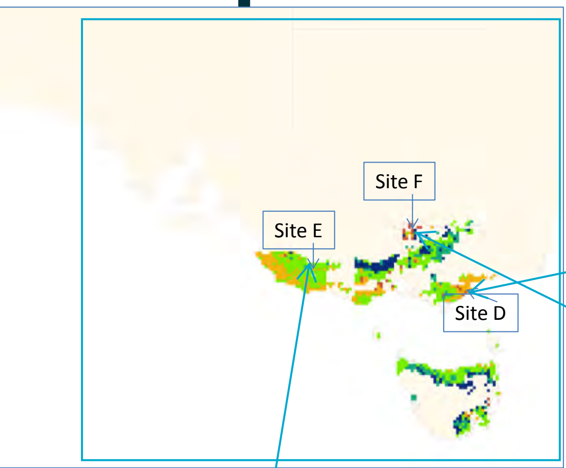
Impact of fertility on responses of *E. globulus* productivity to changing climates, percentage change is shown for 2030. The climate model is the CSIRO MK3.5 GCM, no eCO_2 response and the soils are medium fertility soils and low fertility soils. The depth of the soil remains the same.

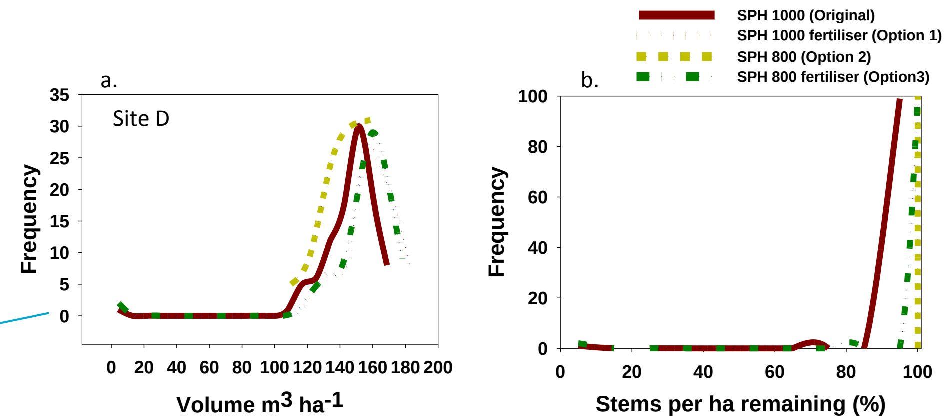
Adapta

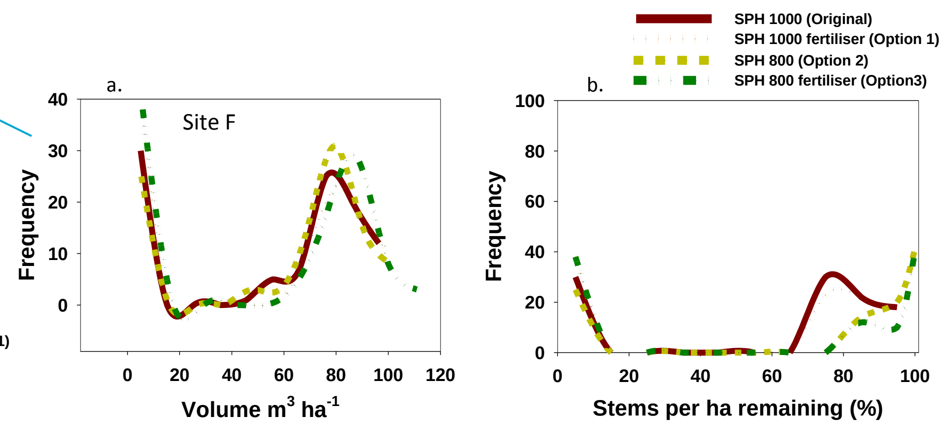


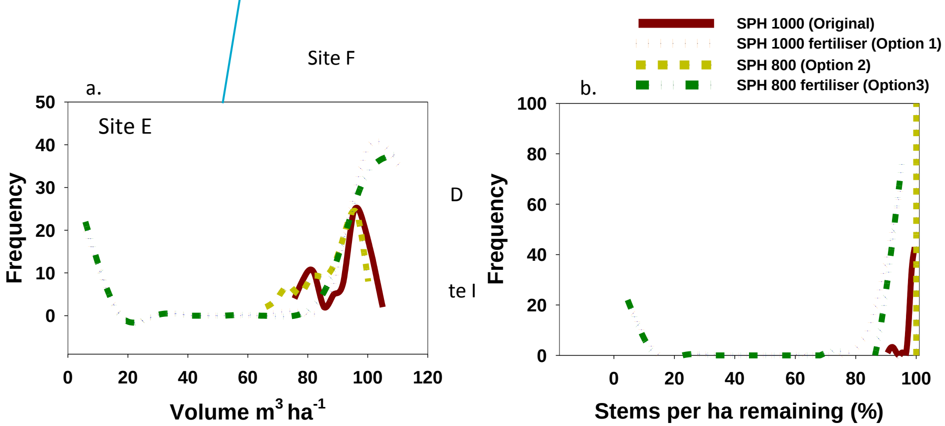
a.
b.
SPH1000 (Original)
SPH800 (Option 1)
SPH800 fertiliser (Option 2)
Site B
Site A
Site C
Site E
Site F
Site D
Site I
Frequency
Volume m³ ha⁻¹
Stems per ha remaining (%)
a. *E. globulus* reference sites
b. *P. radiata* reference sites
Eucalyptus globulus

Adaptation







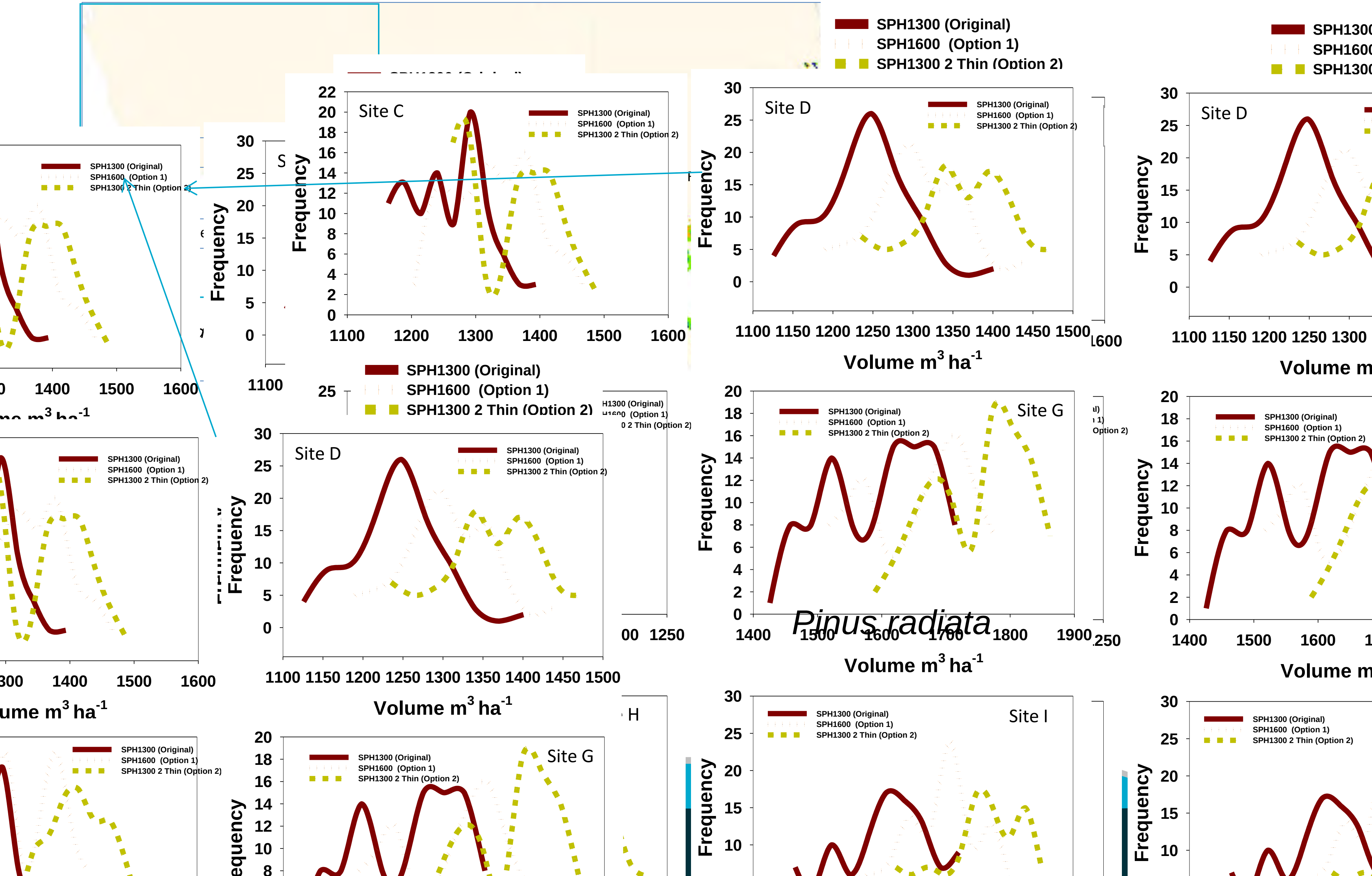


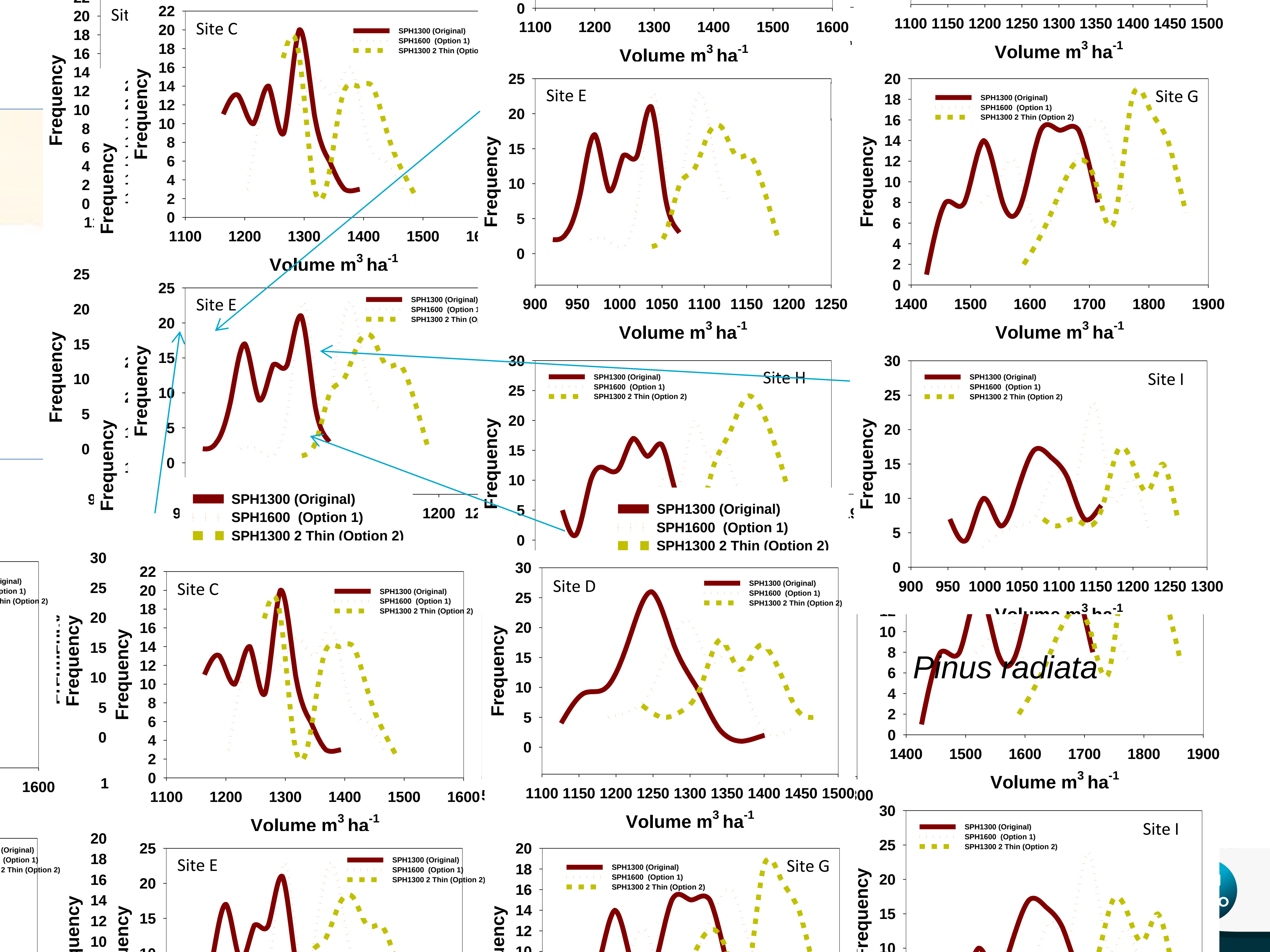
Eucalyptus globulus

Site D

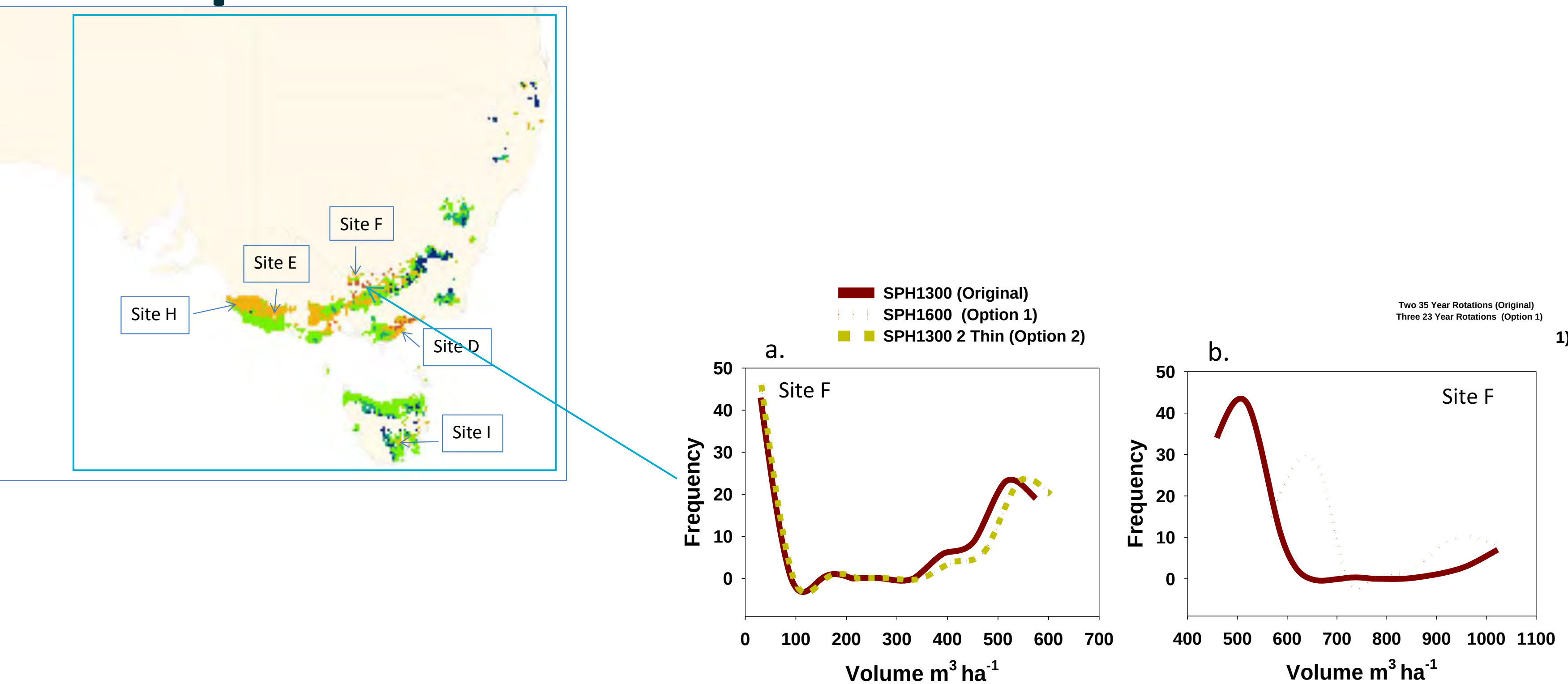
Adaptation

a. *E. globulus* reference sites




Site C
Site E
Site G
Site H
Site I
Site D
SPH1300 (Original)
SPH1600 (Option 1)
SPH1300 2 Thin (Option 2)
Frequency
Volume m^3 ha^{-1}
Pinus radiata

Adaptation



Pinus radiata

Conclusions - impacts

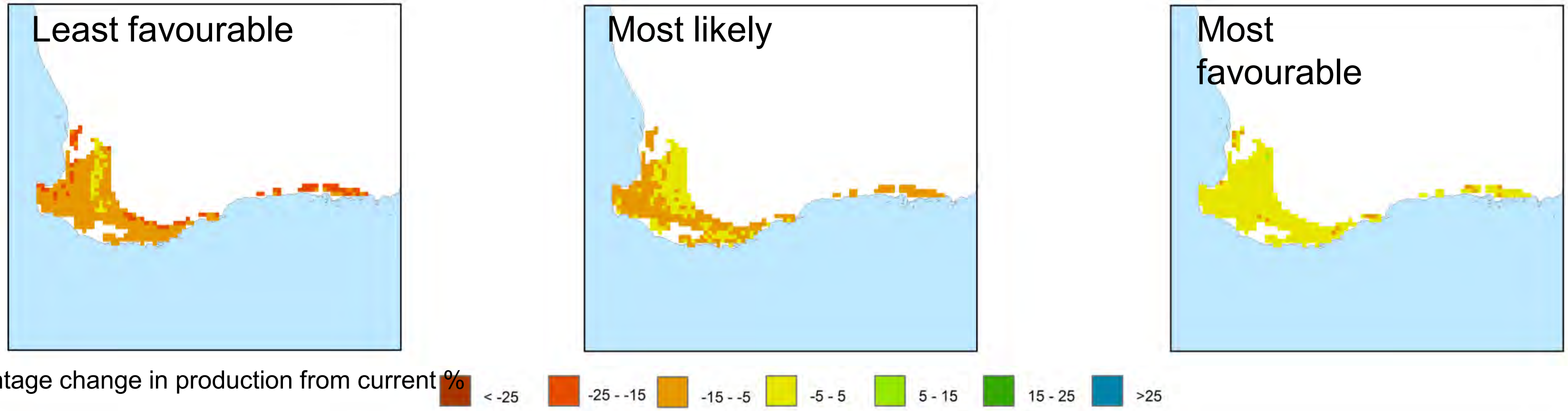
1	Some regions of the Radiata pine and blue gum estates may show decreased productivity in 2030 compared to now. Other regions may show increased productivity however the response will be strongly determined by local conditions of soil depth and fertility.
2	Model predictions are highly sensitive to the responsiveness of plantation species to eCO_2. If forests are not responsive to eCO_2 and sustained photosynthetic rate increases are not observed, 5-15% or higher decreases in productivity may be seen in the Green Triangle, Gippsland and south-west Western Australia may be seen for both bluegum and radiata pine. These are currently some of the most productive plantation areas. If plantations respond favourably to eCO_2, then productivity is predicted to increase in most regions except at the drier margins of the plantation estate where increased mortality will reduce expected production.
3	Cold wet sites (for example plantations in the highlands of Victoria) where nutrients are limited may see an additional growth response due to increased nitrogen mineralisation under warmer temperatures. This benefit is not predicted for drier environments where water is the main resource limiting to growth.
4	We predict a general decrease in survival in warm dry regions if the response to eCO_2 is limited. In cold environments, survival generally improves in response to warmer temperatures.
5	Those sites currently in the well performing core of the plantation estate may be slightly affected in production (up or down) by climate change, but our modelling shows little change by 2030 or even 2050. However, areas at the dry margins of the estate are vulnerable and in the worst instances look highly likely to fail.

Conclusions - adaptation

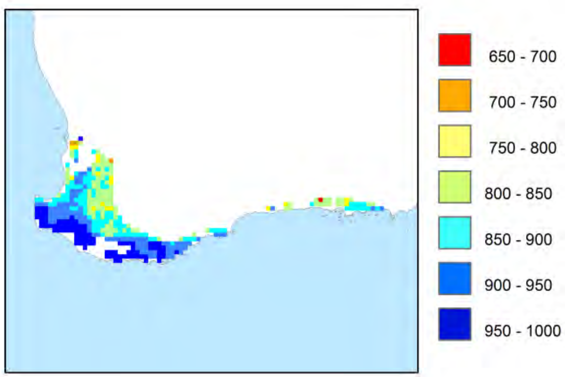
1	For 2030, for many parts of the plantation estate good silvicultural management has the potential to mitigate the negative impacts of climate change.
2	For *E. globulus*, modelling suggests reducing the initial stocking to 800 sph in water limited environments can substantially reduce the risk of mortality in most instances without impacting on productivity. Fertiliser application can increase productivity to current levels but in some cases this will be at increased risk of mortality.
3	For *P. radiata*, modelling suggests that in most cases, increasing the initial stocking to 1600 sph or reducing the number of thinning's to two and delaying the first thinning will increase productivity, though it is uncertain how the risk of mortality will change under this management.
4	For *P. radiata* in very marginal sites, where extreme droughts are possible, shortening the rotation may improve overall productivity by reducing the exposure to extreme events.
5	In locations where no adaptation options could be identified for *E. globulus*, *P. radiata* may be a suitable alternative species to plant.

2030 South-west WA

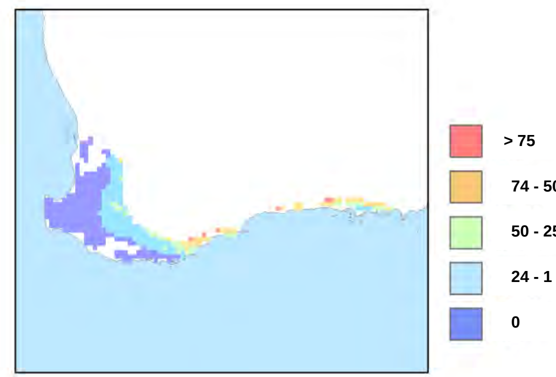
2030 Volume change with no elevated CO_2 (Medium fertility, deep soils)



Percentage change in production from current %



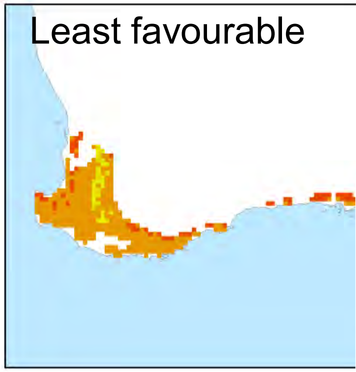
Median Mortality (remaining SPH from 1000)

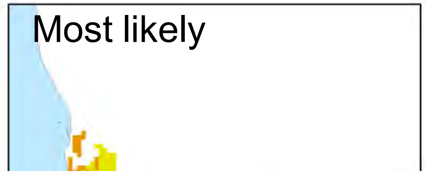


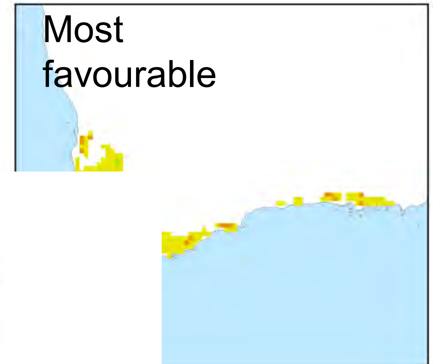
Number of rotations where there plantation failure(out of100)

Eucalyptus globulus in 2030 South-west WA

2030 Volume change with no elevated CO_2 (Medium fertility, deep soils)

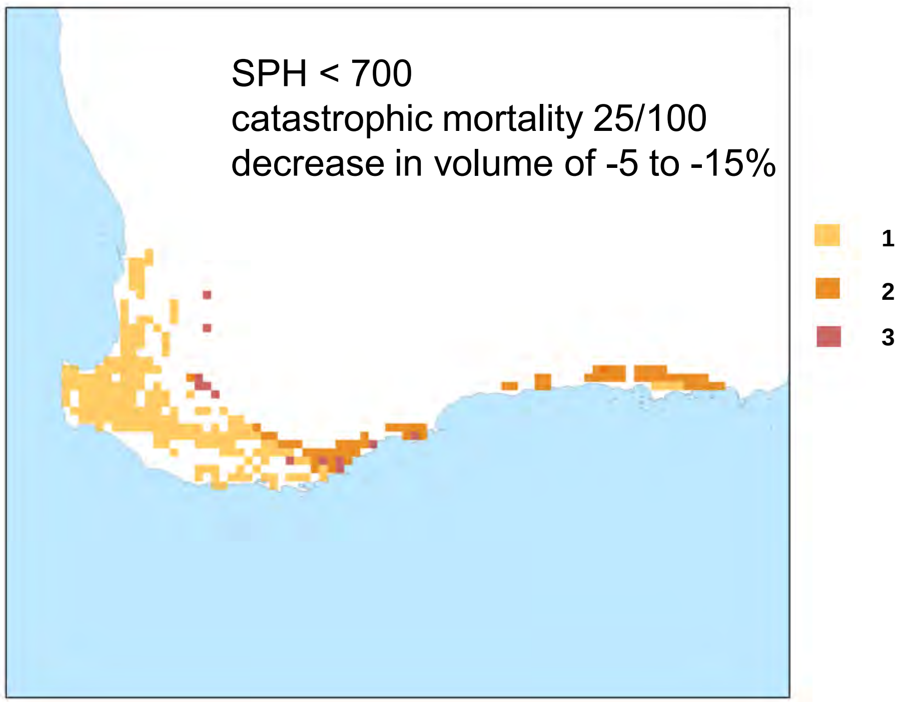


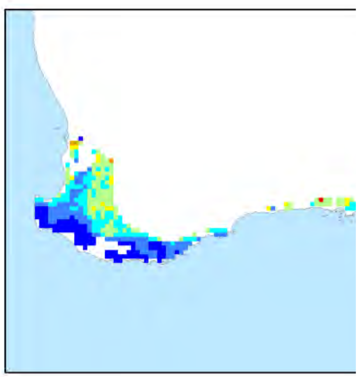




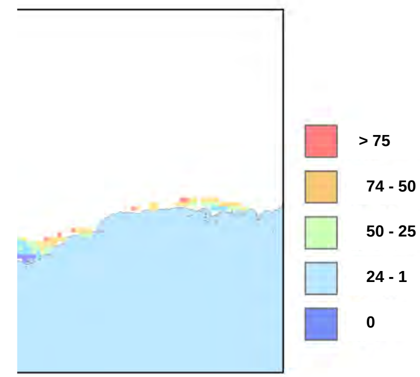
Percentage change in production fron

Risk





Median Mortality (remainin



rotations where mortality
ophic (out of100)

Thank you

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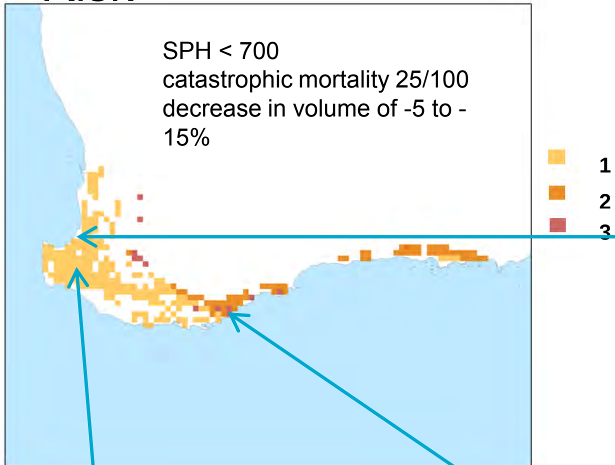
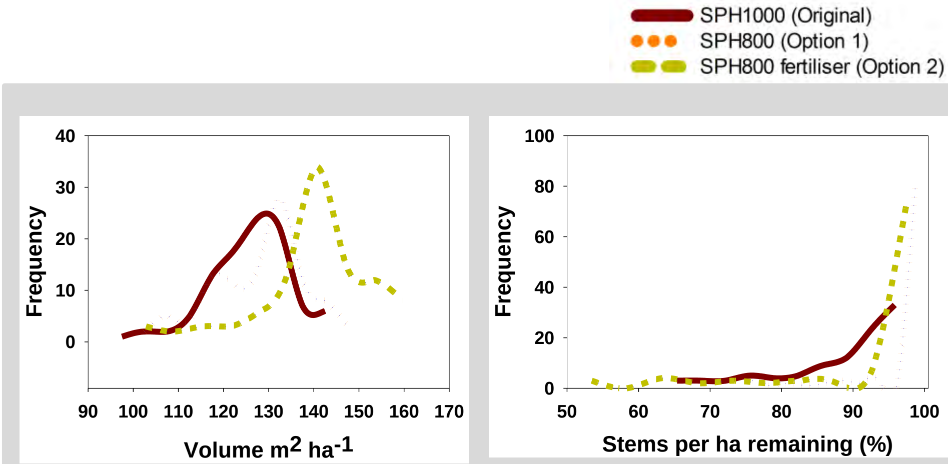
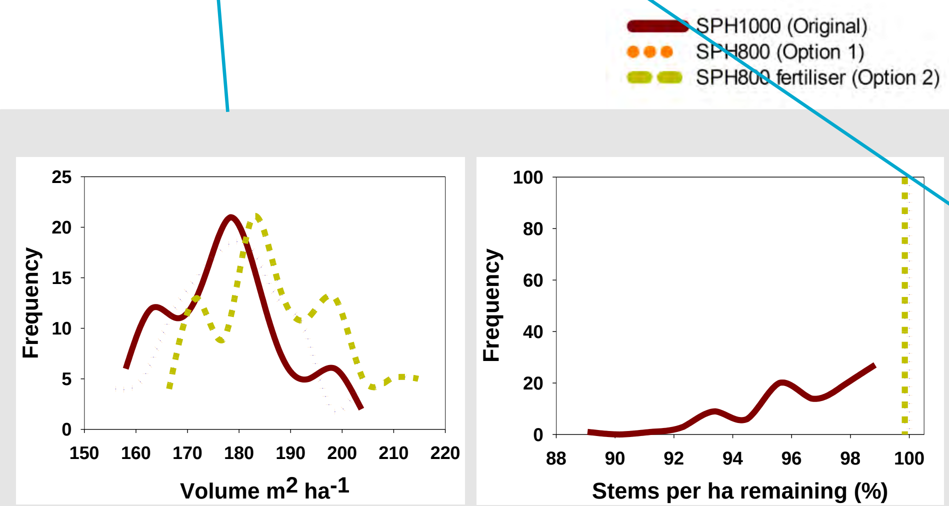
Adaptation to changes in production mortality

Risk





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



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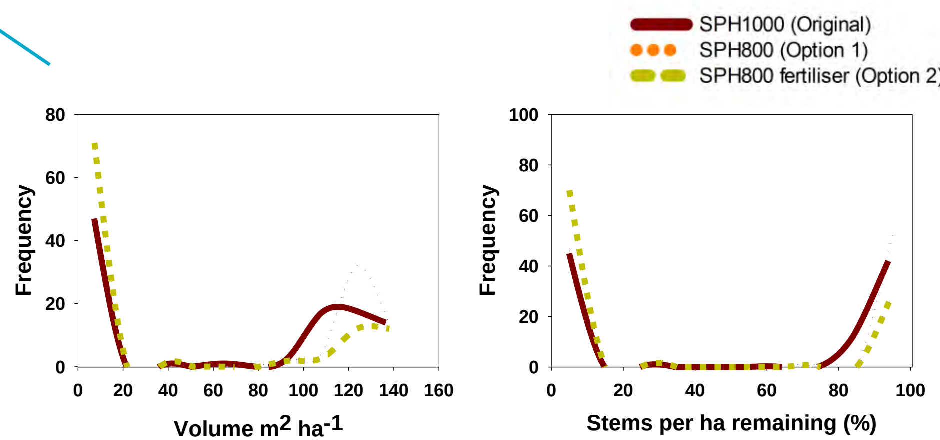

Effects of changes in stocking and fertiliser application on production and mortality

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