The extent and causes of decline in productivity from first to second rotation blue gum plantations

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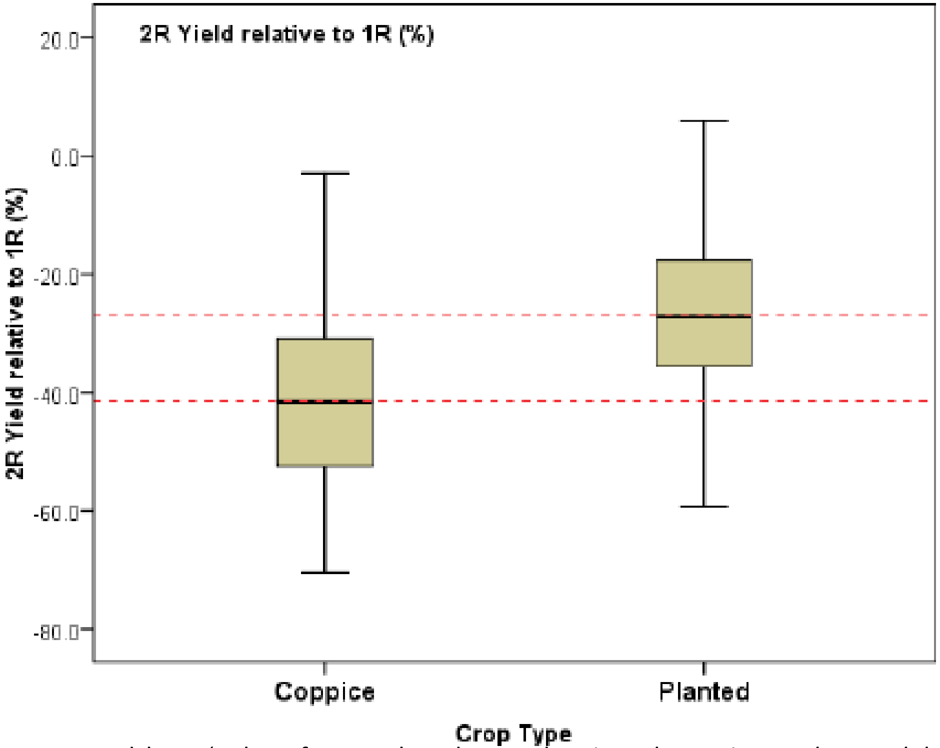


From Ben Bradshaw, ‘Value of research and toward regime change in *Eucalyptus globulus.’*
Presentation to IFA plantation productivity meeting May 14 2014, Mt Gambiar.
http://www.forestry.org.au/ifa-events/ifa-plantation-productivity-symposium/presentations

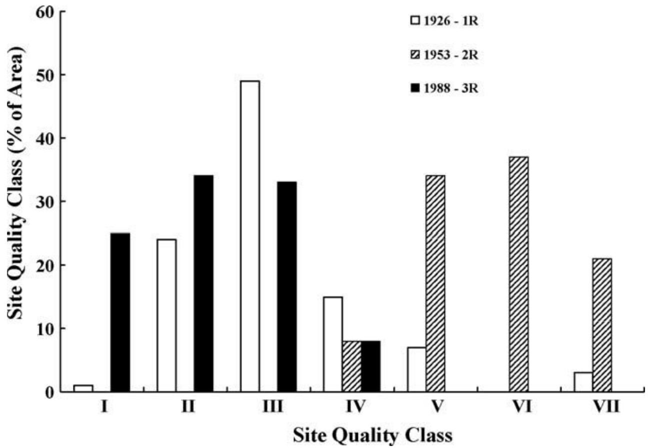
Table 2. Estimates of blue gum plantation production, Great Southern Plantations

Project year	Region	Total area (ha)	Estimated yields (m^3 ha^{-1}) at age 10 years		
			Low	High	Weighted average
1998	Albany, WA	3724	105	197	140
1999	Albany, WA	3685	60	264	152
2000	Albany, WA	10269	92	280	147
2001	Albany, WA	1869	85	257	142
2002	Albany, WA	2308	63	269	168
2003	Albany, WA	4720	n.a.	n.a.	153
Weighted mean					149.2

To cite this article: Ian Ferguson (2014) Australian plantation inventory: ownership changes, availability and policy, Australian Forestry, 77:1, 25-38, DOI: 10.1080/00049158.2013.868766

Some precedent here

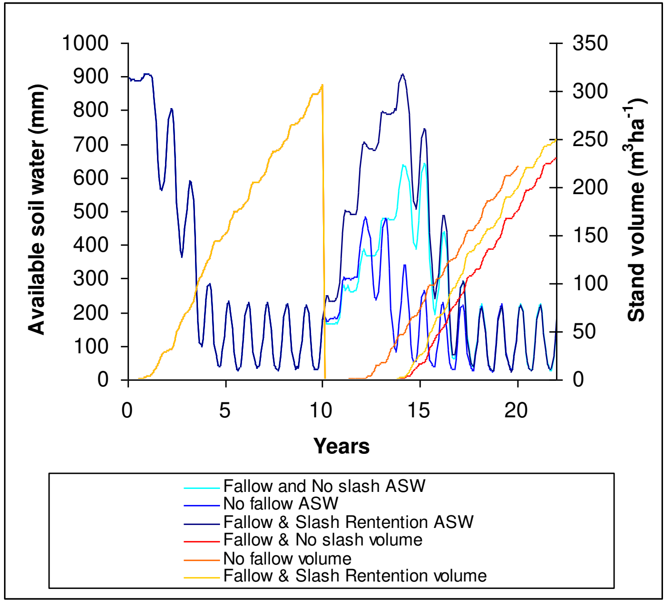
Fig. 3. Site quality maps of three successive rotations in the same area at Penola forest.

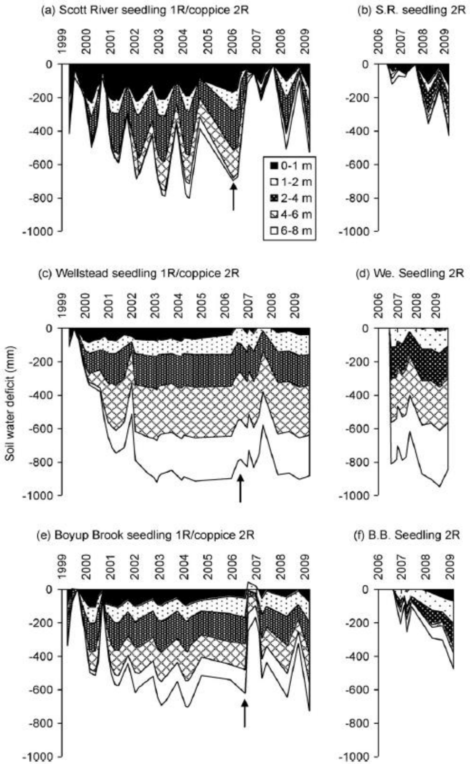


J.F. O'Hehir, E.K.S. Nambiar / Forest Ecology and Management 259 (2010) 1857–1869

Identified as issue 1999 in 'Balancing Productivity and Drought Risk in Blue Gum Plantations' Ed. DA White

Mendham et al. 2011. Soil water depletion and replenishment during first- and early second-rotation Eucalyptus globulus plantations with deep soil profiles. Agricultural and Forest Meteorology **151:1568-1579.**





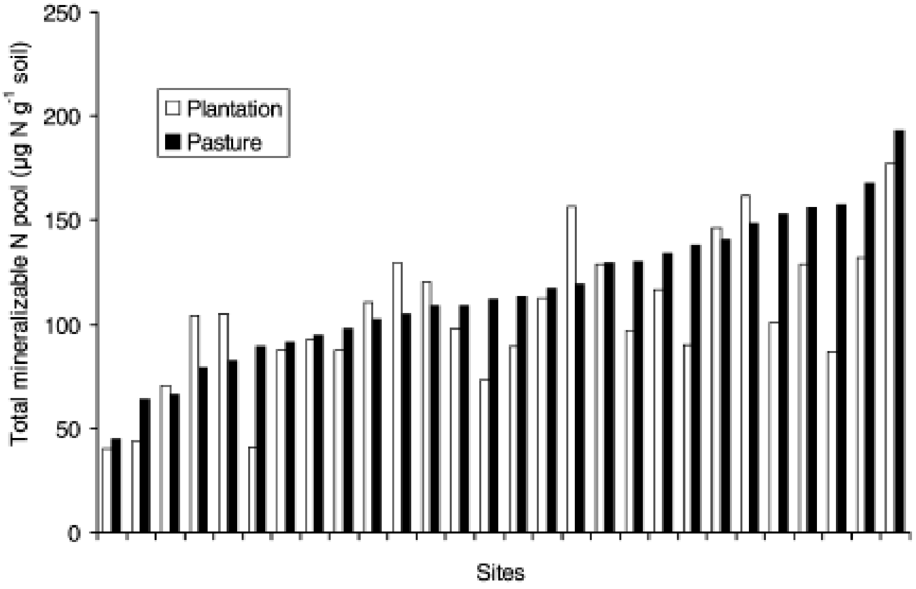


Fig. 3. Variation in the total mineralizable N pools ($\mu g\ N\ g^{-1}$ soil) across 28 eucalypt plantation and pasture paired sites determined by fitting Eq. (1) to the cumulative N mineralized in long-term laboratory incubations.

“These results suggest that N supply rates of pasture soils are likely to decline when the land is planted to successive crops of eucalypts. Eucalypt plantation managers will need to take account of this and implement management strategies to maintain adequate N nutrition to sustain tree growth in future rotations. “

A.M. O'Connell et al. / Soil Biology & Biochemistry 35 (2003) 1527–1536

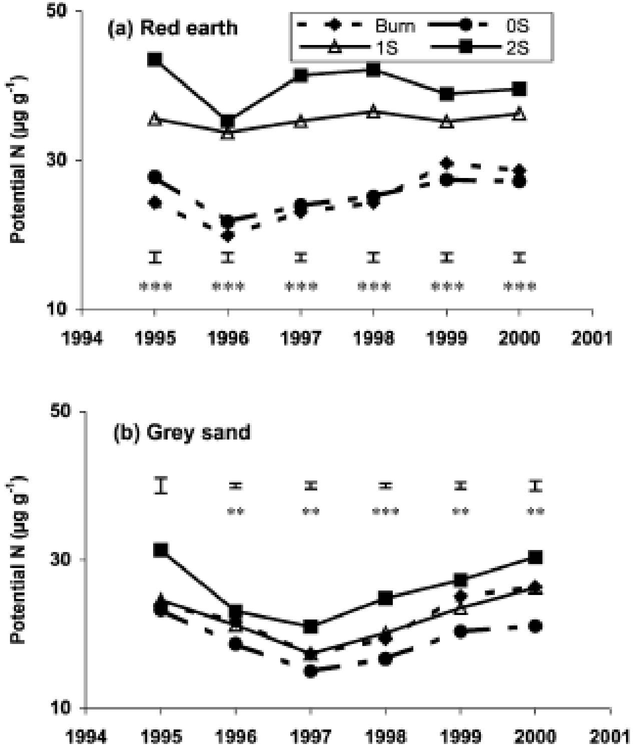
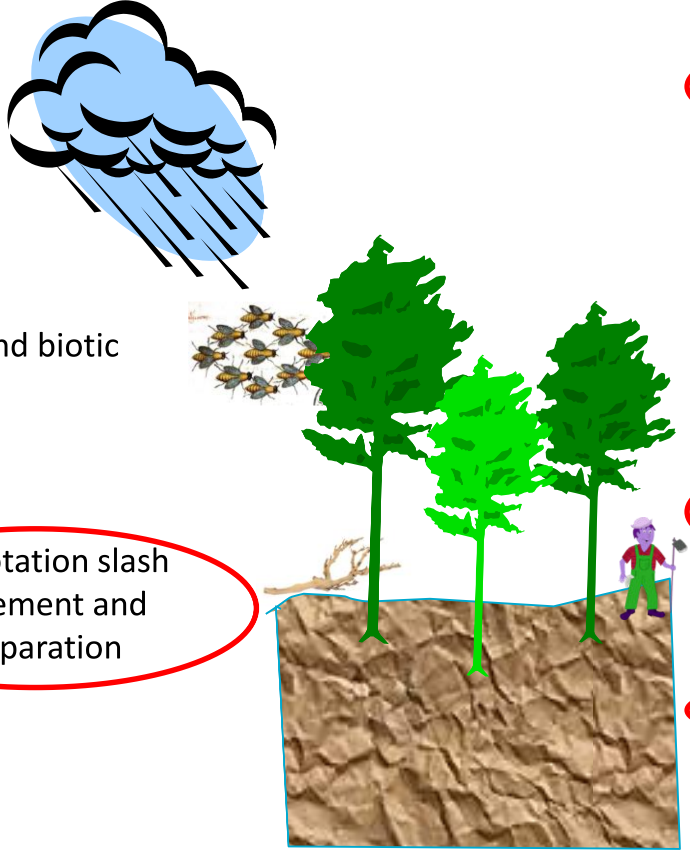


Fig. 5. Annual average concentrations of potentially mineralizable N (anaerobic incubation) in surface soil (0–10 cm) in relation to harvest residue treatments at (a) the red earth site and (b) the grey sand site. Values are the mean of 13 measurements taken at 4-weekly intervals each year. Standard errors and ANOVA significance levels shown for each year (* $P < 0.05$; ** $P < 0.01$).

"Retaining harvest residues will contribute to enhanced N supply for the next tree crop through mineralization in the long term. However, on some sites, additions of nitrogenous fertilizers will still be required to maximise the rate of tree growth."

A.M. O'Connell et al. / Soil Biology & Biochemistry 36 (2004) 39–48



Weather during the rotation

Pests and biotic factors

Changes in genetics or seedling stock

Management inputs (fertiliser, thinning, stocking)

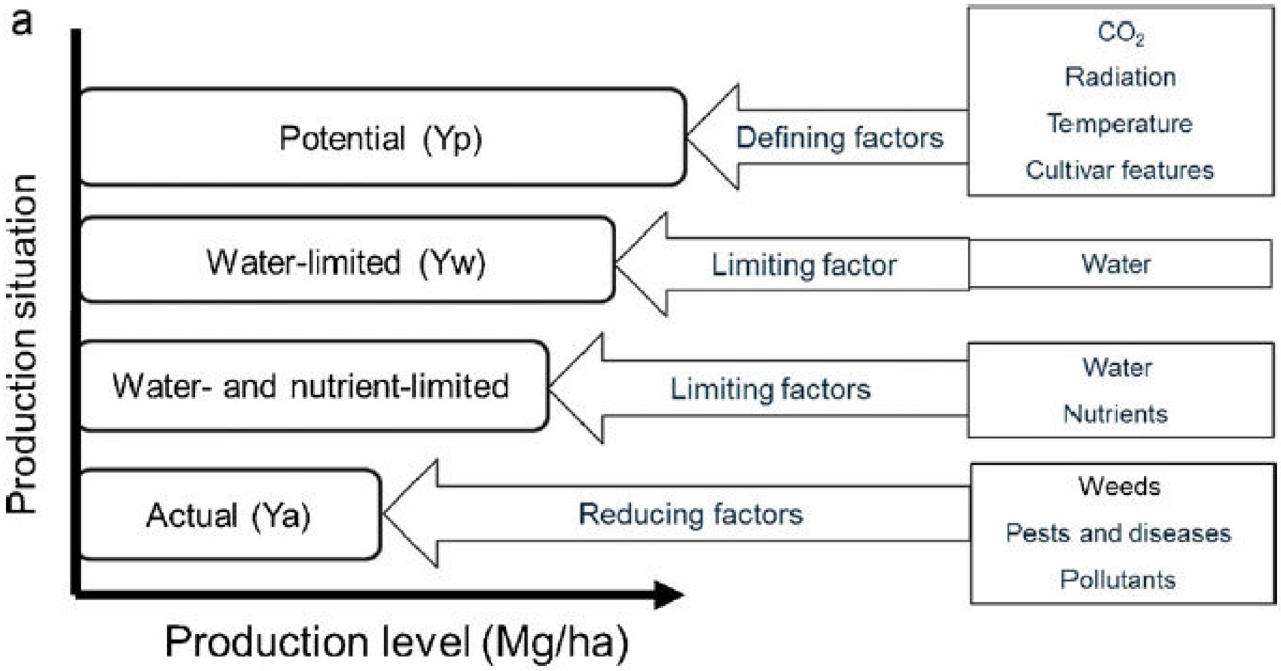
Inter-rotation slash management and site preparation

Soil water

Soil nutrition / chemistry

Soil physical properties (pH, compaction and pugging, wet ability..)

Yield gaps



M.K. van Ittersum et al. / Field Crops Research 143 (2013) 4–17

Plot yield gap analysis

Weather and soils descriptions of plots

Simulation with observed weather and silviculture

Factor analysis:
-1R and 2R weather
-soil water at start of rotation
-nutrient limits

Company long term growth plots (12 plots with 1R and 2R growth and good soils data)

Comparison observed and predicted in 1R and 2R

Residual analysis, what has changed and what remains unexplained

Spatial analysis

Spatial weather and soils data

SILO 10km grid	Deep and shallow, fertile and infertile combinations

Silviculture

Residue management

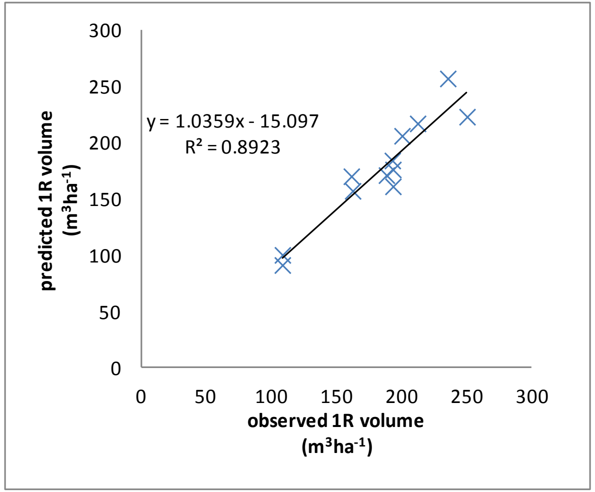
Simulation, mapping and analysis

Sites and summary of conditions used in analysis. Site names are the first rotation name and inventory number.

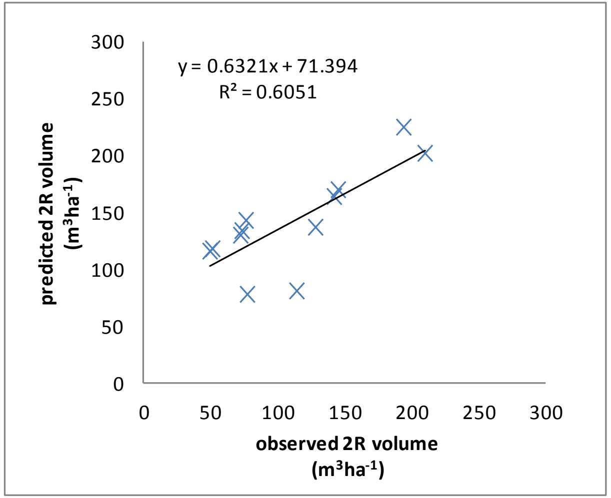
Site	OC (%) 0-10cm	CN 0-10cm	Soil Depth (cm)	Max ASW Profile (mm)	Av Annual Rainfall (mm)	Av Annual Evap (mm)	Insect damage in 2R
Caile301	2.58	15	480	520	654	1331	High
Carpe253	3.18	15	600	797	1097	1198	Low
Dunne256	1.15	30	780	511	973	1284	Low
Dunne340	4.02	12	900	820	959	1293	Low
Gardiner304	4.68	12	900	979	952	1457	Low
Linds260	2.97	35	200	291	933	1249	Low
Lovel203	3.98	30	560	557	691	1344	High
Lovel206	4.13	22	600	466	658	1366	High
Seato326	5.23	12	900	1658	616	1311	High
Tippe335	4.21	12	601	503	595	1327	High
Warde245	4.96	12	450	455	653	1326	High
WrenP217	3.36	16	435	553	954	1213	Low

Predicted first and second rotation annual nitrogen available to plantations (total mineralised nitrogen less immobilised nitrogen)

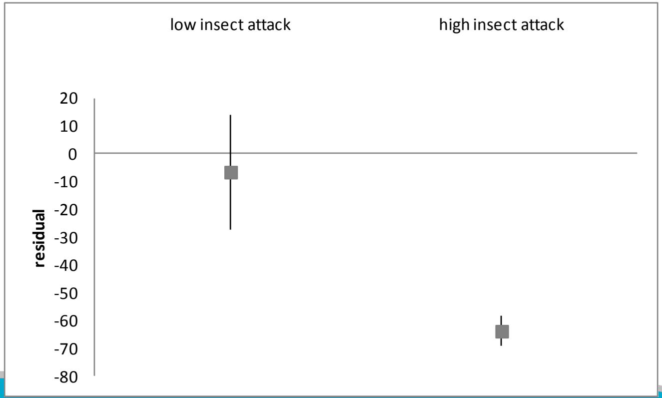
Site	First rotation (kg ha $^{-1}$)	Second rotation (kg ha $^{-1}$)
Caile301	66	55
Lovel206	130	96
Lovel203	92	81
Seato326	118	103
Tippe335	103	91
Warde245	110	105
Carpe253	93	81
Dunne256	26	20
Dunne340	120	97
Linds260	89	83
WrenP217	96	85
Gardiner304	109	89



300
250
200
150
100
50
0
y = 1.0359x - 15.097
R² = 0.8923
predicted 1R volume
(m³ha⁻¹)
0 50 100 150 200 250 300
observed 1R volume
(m³ha⁻¹)



300
250
200
150
100
50
0
y = 0.6321x + 71.394
R² = 0.6051
predicted 2R volume
(m³ha⁻¹)
0 50 100 150 200 250 300
observed 2R volume
(m³ha⁻¹)



low insect attack
high insect attack
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
residual

Site	1R average water stress to same age 2R (MPa)	2Rstress average water stress (MPa)
Caile301	-1.38	-1.40
Lovel206	-1.21	-1.28
Lovel203	-1.17	-1.43
Seato326	-1.17	-1.61
Tippe335	-1.39	-1.56
Warde245	-1.26	-1.41
Carpe253	-0.85	-1.00
Dunne256	-1.35	-1.38
Dunne340	-1.41	-1.55
Linds260	-1.33	-1.36
WrenP217	-0.97	-1.08
Gardiner304	-0.69	-0.71

Table 19 Predicted first and second rotation average leaf water potential (a measure of water stress – lower numbers equate to greater stress).

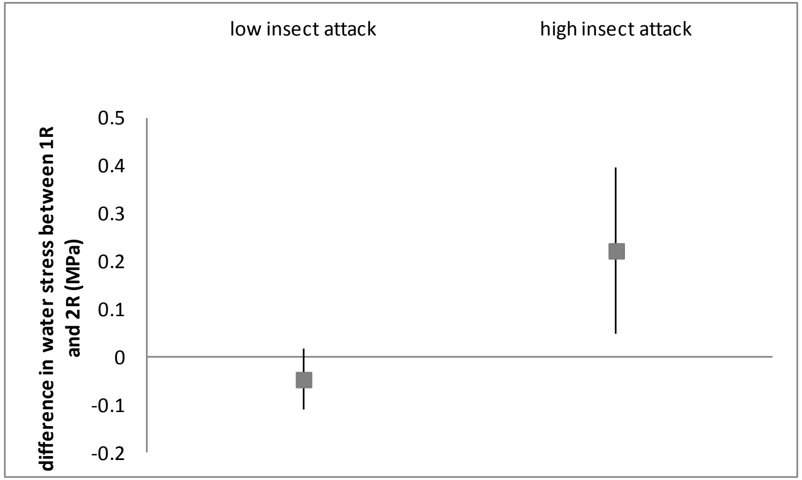
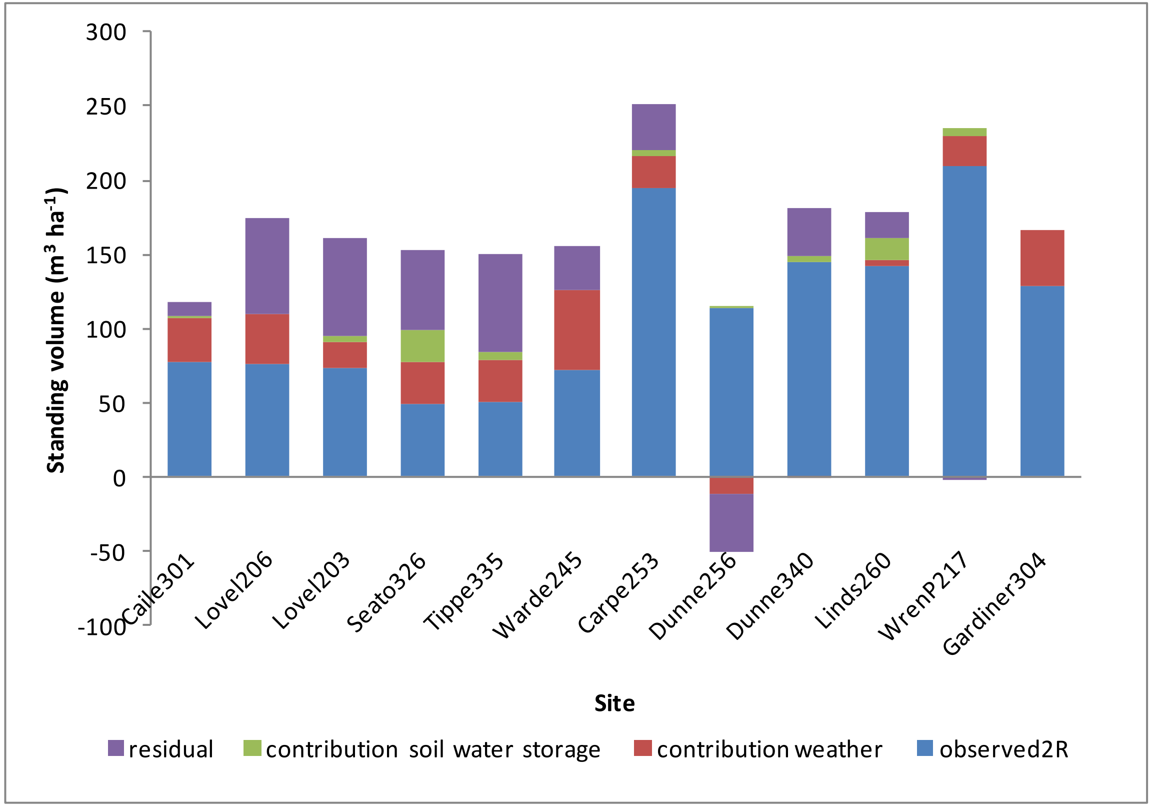


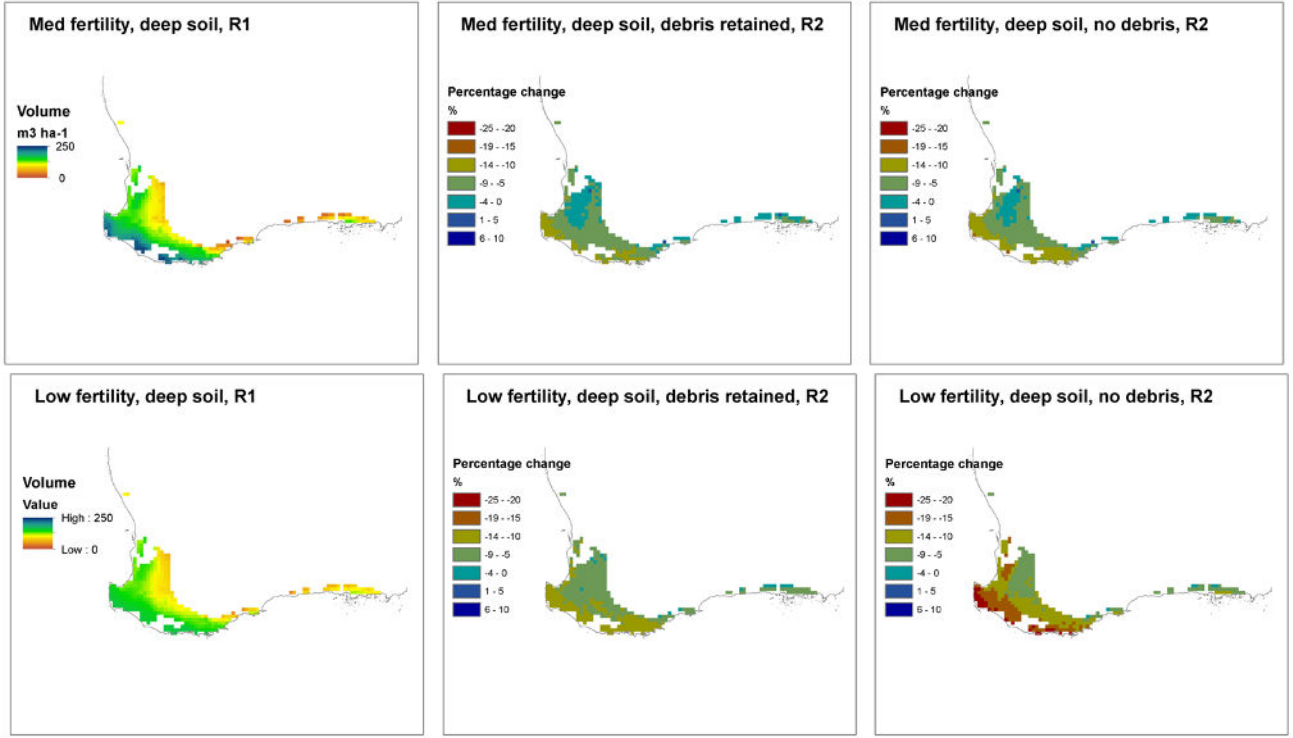
Figure 12 Predicted difference between 1R and 2R average rotation water stress for plantations observed with high and low insect damage, the 95% confidence interval of the mean is shown for each class of attack. Only plots for which significant water stress was observed are included in the analysis, Carpenters253 and Wrens217 where average rotation water stress in the 1R and 2R was less than -1MPa are excluded although both showed an increase of 2R water stress of approximately 0.15 MPa (Table 2).



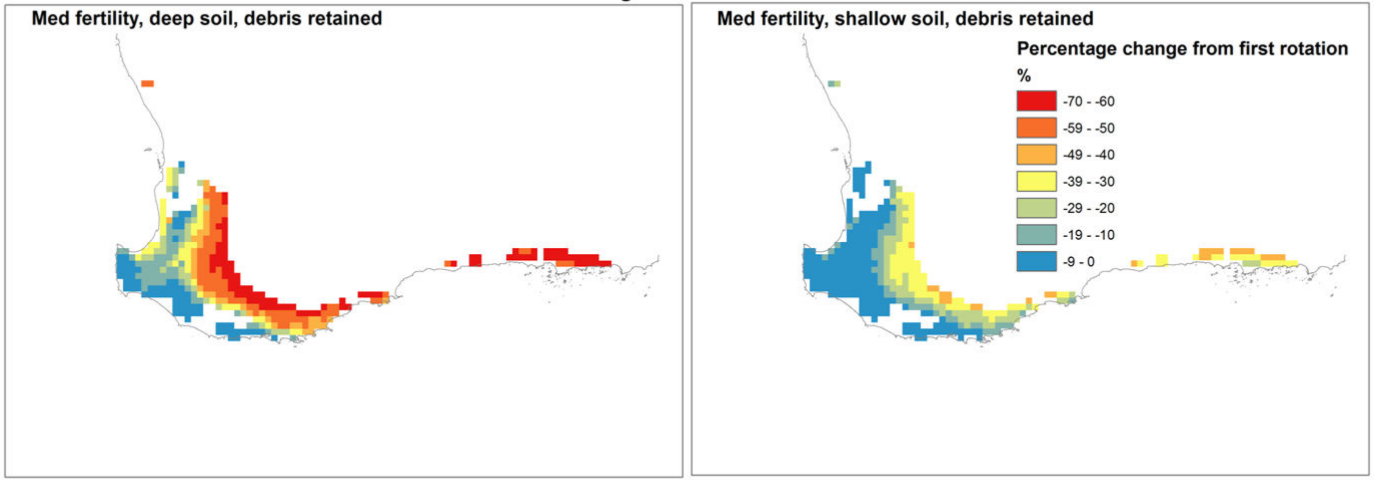
Standing volume (m3 ha-1)
300
250
200
150
100
50
0
-50
-100
Caile301
Lovel206
Lovel203
Seato326
Tippe335
Warde245
Carpe253
Dunne256
Dunne340
Linds260
WrenP217
Gardiner304
Site
residual
contribution soil water storage
contribution weather
observed2R

Factor	Contribution to decline	minimum	maximum
Soil water change	-5 m3/ha or -3%	0	-20 m3/ha or -50%
Weather	-22 m3/ha or -13%	+ 12 m3/ha or 10%	-54 m3/ha or-28%
Residual (insect)	-27 m3/ha or -15%	+39 m3/ha or 39%*	-66 m3/ha or 41%
Nutrient	No nutrient effect on these high nutrient sites – this will not be typical		

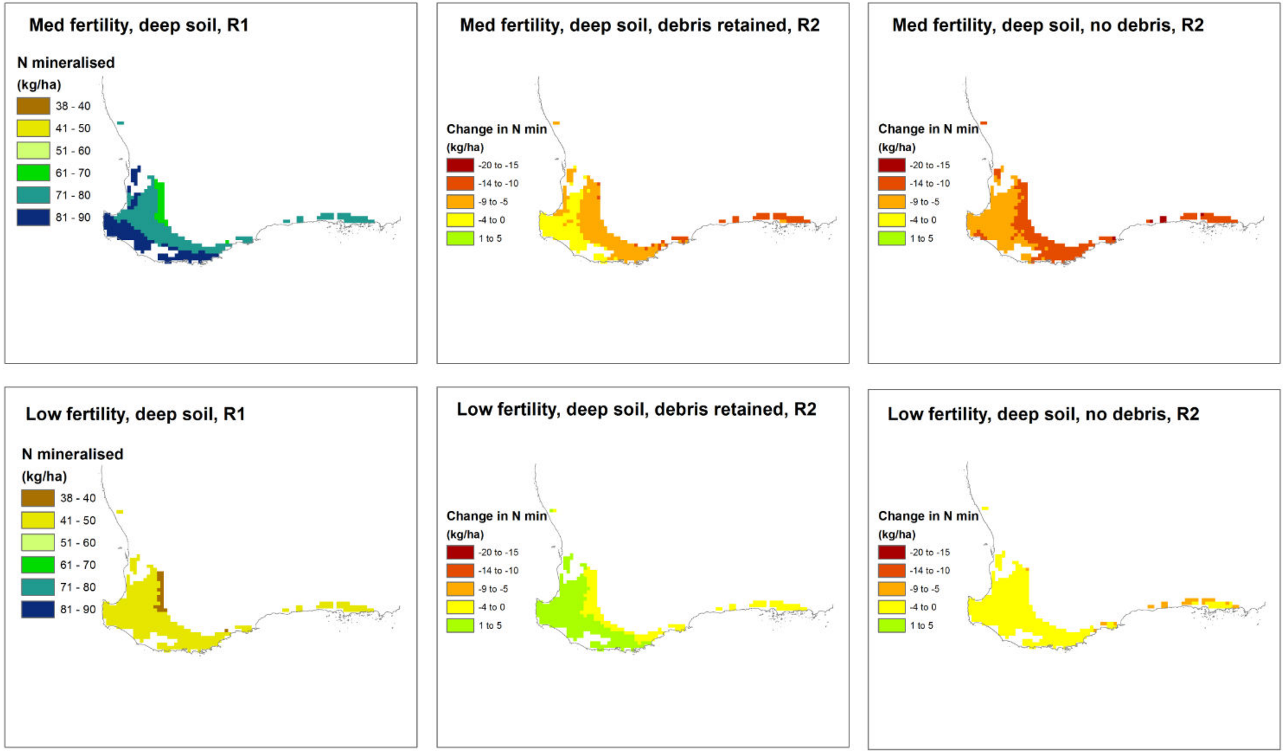
* Dunne256 grew a lot more in the second than the first rotation – there is a large unexplained factor here



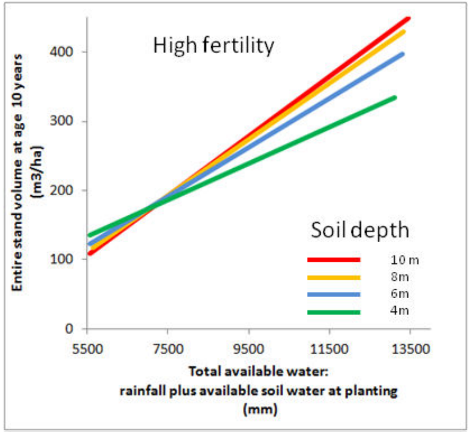
Spatial prediction of 1R production, and change into the second rotation assuming fertility is low (0-10 cm soil organic C=) or moderate (0-10 cm soil organic C=) and soils deep, soil depth 10m), where the logging residues are left distributed on the site or removed (this could be windrow and burnt, or whole tree harvesting).

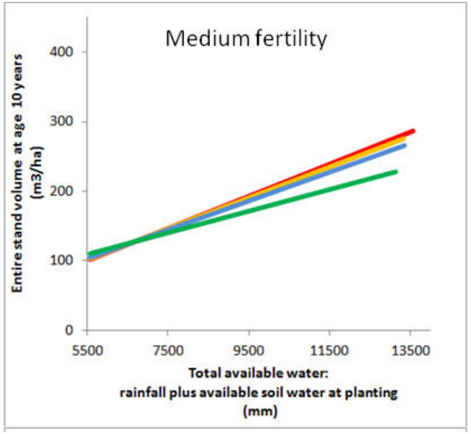


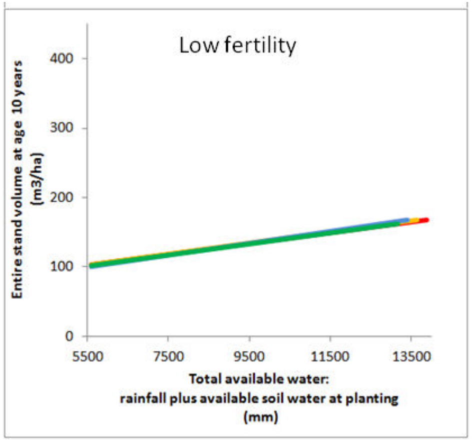
Percentage change in plant available soil water from the start of the first to the start of the second rotation with debris retention and on deep and shallow soils.

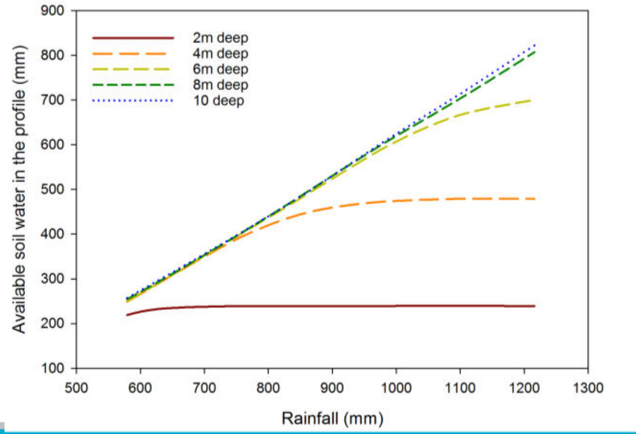


Average annual nitrogen net mineralisation (kg N ha^{-1} yr^{-1}) in the first and second rotation with and without slash (debris) retention.


High fertility
Entire stand volume at age 10 years (m3/ha)
400
300
200
100
0
5500
7500
9500
11500
13500
Total available water:
rainfall plus available soil water at planting
(mm)
Soil depth
10 m
8m
6m
4m

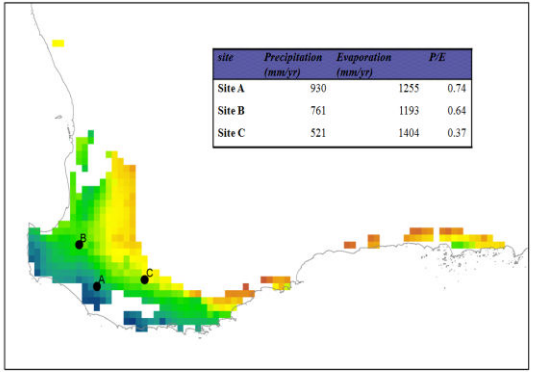

Medium fertility
Entire stand volume at age 10 years (m3/ha)
400
300
200
100
0
5500
7500
9500
11500
13500
Total available water:
rainfall plus available soil water at planting
(mm)


Low fertility
Entire stand volume at age 10 years (m3/ha)
400
300
200
100
0
5500
7500
9500
11500
13500
Total available water:
rainfall plus available soil water at planting
(mm)


Available soil water in the profile (mm)
900
800
700
600
500
400
300
200
100
500
600
700
800
900
1000
1100
1200
1300
Rainfall (mm)
2m deep
4m deep
6m deep
8m deep
10 deep

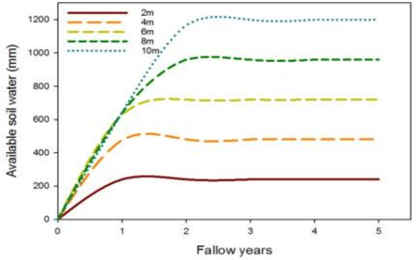
Decrease in production from first rotation to second rotation (m3/ha) due to decreased soil water storage following first rotation depeletion for different soil depths in area of different mean annual rainfall in South West Western Australia (radiation and VPD are that site C from Figure 20).

	rainfall (mm/year)		
soil depth	**700**	**900**	**1100**
2m	0.0	0.0	0.0
4m	1.9	0.3	0.0
6m	4.7	2.4	0.0
8m	8.0	5.0	2.0
10m	11.3	8.3	5.3

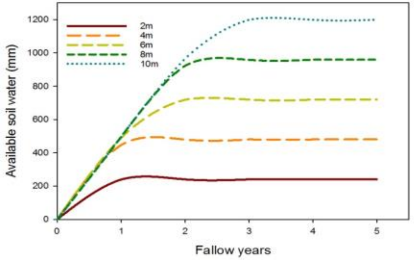


site	Precipitation (mm/yr)	Evaporation (mm/yr)	P/E
Site A	930	1255	0.74
Site B	761	1193	0.64
Site C	521	1404	0.37

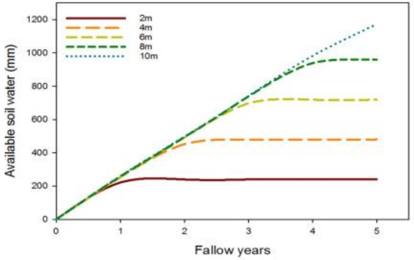
Site A



Site B



Site C



Recharge rates at three example locations is south west Western Australia. Site A (Lat. 34.45 , Long. 116.15) is slightly west of Pemberton with a mean annual rainfall of 930 mm, site B (Lat. 33.85 , Long. 115.85) is close to Nannup with a mean annual rainfall of 761mm and Site C (Lat. 34.35 , Long. 116.95) is close to Quinninup with a mean annual rainfall of 531mm.

Site type	Likely risk of 2R decline	Comments
Shallow soil, ex-pasture	**High**	**While high relative impact, absolute impact likely to be low due to low first rotation productivity. High mortality risk from drought in 1R and 2R. Nevertheless if such sites are to be retained in production, careful management of nutrient capital and organic matter inputs is required to sustain site productive potential.**
Shallow soil, ex-bush	**Moderate**	**Managing nutrition and soil organic matter will be critical through multiple rotations, but production will be low. Drought mortality risk moderate, but will increase as site fertility is increased requiring judicious risk management**
Moderate soil depth, ex-pasture	**Moderate**	**Low reliance on first rotation for stored water to drive production may see only modest change, but moderate to high production in first rotation may place significant demands on soil nutrition which may require management into subsequent rotations. Drought mortality and pest risk may be exacerbated into 2R**
Moderate soil depth, ex-bush	**Low**	**Low reliance on first rotation for stored water to drive production may see only modest change, and unless fertilisation was high in first rotation productivity was already nutrient limited. With appropriate residue management production should not markedly decrease, but with good fertiliser inputs and organic matter management should increase through multiple rotations. Drought mortality and pest risk may be exacerbated into 2R by early water-stress to young plantations.**
Deep soils, ex pasture	**High**	**The first rotation will have significantly benefited from stored soil water and high nutrient capital. Both sets of resources will be depleted moving into the second rotation. Given high productivity of these sites similar percentage changes in production to other sites will result in large absolute changes in production. There is considerable potential to improve both productivity and uniformity of site quality through multiple rotations with best practice management.**
Deep soils, ex bush	**Moderate**	**The first rotation will have significantly benefited from stored soil water but unless significant fertiliser inputs were added production was probably limited by fertility. Realising the site productive potential will require fertiliser inputs and management of soil chemical and physical properties. There is considerable potential to improve both productivity and uniformity of site quality through multiple rotations with best practice management.**

Acknowledgements

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