Condition of NSW North Coast Private Forest

Alex Jay

BlueChip forest services

tel 04 2725 7545 email alex@bluechipforestry.com.au **July 2017**

report to NSW Department of Primary Industries

Condition of NSW North Coast Private Forest

Contents

NOTE : The figures in this report are scaled for convenience of viewing on one page, and in some cases may not be clearly readable if printed to hardcopy. For clarity, view on screen at high zoom.

Condition of North Coast Private Forest

Introduction & Aim

This report presents a summary and analysis of the condition of 840 forest plots measured in upper north-east New South Wales private native forests (uneNSW PNF) between 2004 and 2013. Locations are shown in Figure 1. The report has been commissioned by the NSW Department of Primary Industries, who are undertaking an assessment of north coast private native forests.

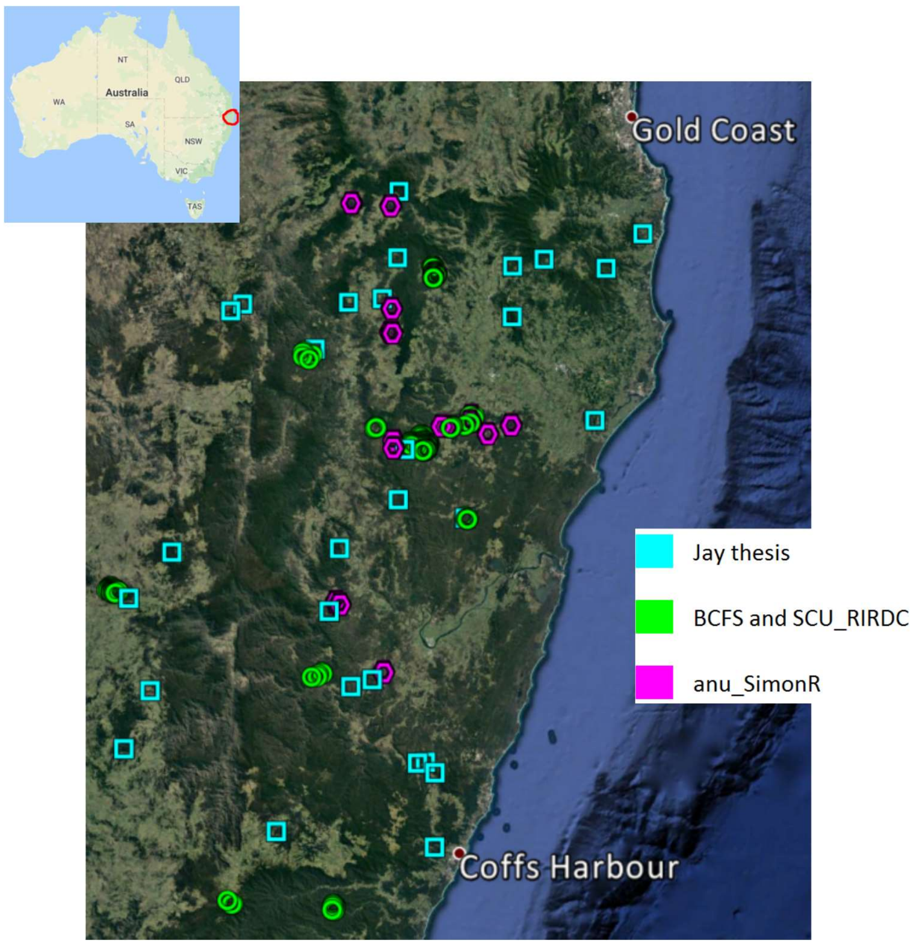


Figure 1 : Location of 840 PNF plots measured in upper northeast NSW.

See Data section for explanation of plot names.

Base map source Google Maps

“Condition” means stand condition, and incorporates many of the factors that would influence a silvicultural decision at stand level, viz, the amount and relative distribution of stocking (or stand basal area) in different diameter (DBH) size classes, grouped by species, crown vigour, and log product grade.

In particular, the plot information is compared to recent aerial photo interpretation (API) mapping which assigned map polygons to one of two classes; even-aged or multi-aged.

Data

The full list of 840 plots on 32 locations contains data from several sources, namely

- JAY_thesis : n=102 plots, 11 locations. Private research undertaken by the author for a PhD study (not yet complete). Plots selected by stratified random sampling; strata = forest type and local government areas with principal occurrences of forest type.
- BCFScomm : n= 268 plots , 6 locations. Consultancy work undertaken by the authors' business, BlueChip Forestry Services, plots selected by stratified random sampling; strata = forest type across representative range of site quality (SQ) on a single large property.
- SCU_RIRDC_bcfs : n= 83 plots, 4 locations. Research work undertaken with an SCU team and published by RIRDC, refer to publication for full details. Dry Spotted Gum forest type with nominal structural or location elements, regrowth, near riparian zone, big old trees, recently logged etc.
- anu_SimonR: n= 385 plots, 11 locations. Private research work undertaken by Simon Roberts at ANU (unpublished), and used here with consent of Mr Roberts. Plots selected by stratified systematic sampling, grid of sample points overlaid on selected forest type.

74 plots of the full list plots were outside the uneNSW zone, but were included for some analyses as they contained the same forest types and were geographically close to the edges of the zone.

Not all plots (eg anu SimonR) had records of crown class (vigour) and log grade, so these attributes were summarised only for 379 plots within the uneNSW zone. 214/379 points fell within API mapped age class polygons (81 even-aged, 133 multi-aged). These 214 plots are referred to now as the “short list”.

Table 1 shows that the full list and short list of plots encompassed most forest types, with an extra weighting on both dry Spotted Gum and dry Blackbutt types. Dry sclerophyll types (eg grey gum, red gum) forest were under-represented in the full list data compared to ground area. Tableland forests also appear to be under-represented, however 50 of the 74 out-of-zone plots (Forest Type #N/A) were in tablelands forests (dry, moist and stringybark).

Table 1 : Extent of uneNSW PNF and plot distribution by forest type

		UNE NSW PNF			Short list%	
Forest type	**description**	**Ha gross**	***Gross%***	**Full %**	**Even %**	**Multi %**
mBBT	blackbutt-moist	13,160	*2%*	*4%*	*4%*	*12%*
dBBT	blackbutt-dry	71,724	*8%*	*17%*	*19%*	*23%*
FLG	flooded gum	8,369	*1%*	*1%*		*2%*
BBX	brushbox	14,199	*2%*	*1%*		*2%*
MCE	moist coastal eucalypts	50,402	*6%*	*2%*		*7%*
smTDE	semi-moist and taller dry eucalypts	110,576	*13%*	*12%*	*22%*	*15%*
mSPG	spotted gum- moist	4,897	*1%*			
SPG	spotted gum- dry	166,213	*19%*	*41%*	*56%*	*25%*
DSW	dry sclerophyll and woodlands	178,769	*21%*	*9%*		*12%*
TEM	tableland eucalypts-moist	91,132	*11%*	*1%*		
TED	tableland eucalypts-dry	74,928	*9%*	*0%*		
TSB	tablelands stringybarks	76,960	*9%*	*0%*		
NPT	negligible productive types			*0%*		
Rf	rainforest			*0%*		
OTH				*2%*		*2%*
#N/A	not in mapped UNE polygon			*9%*		
		861,329	ha	n=840	n=81	n=133

Source of area data : NSW CRAFTII mapping 1998. Total may not match exactly with current areas because of changes in tenure or clearing since the original mapping.

Figure 2 shows the distribution of tree sizes and plot densities in the data.

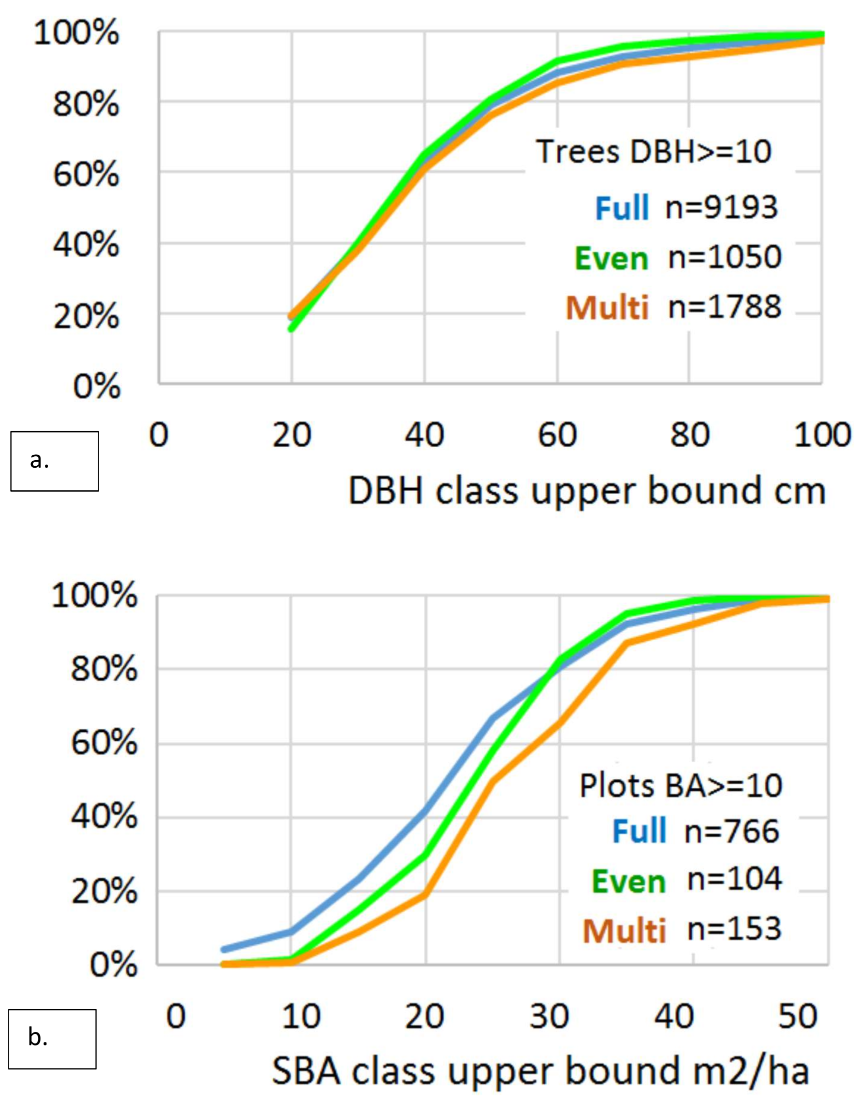


Figure 2 : Histograms of plot data

a. Cumulative frequency of sampled tree sizes in 10cm DBH intervals

b. cumulative frequency of plot SBA in 5 m2/ha intervals

Cumulative frequency is plotted against the maximum of the class interval. Hence the lines show the percentage of sample trees or points which are less than the value read on horizontal axis.

Fig 2a shows that the distribution of tree size (DBH) in the plot sweeps was very similar for the full list and for even and multi-aged classified plots in the short list. About 40% of the measured trees >10cm DBH in each list were less than 30cm DBH. Some 80% of the total number of measured trees are less than 50cm DBH, and only about 10% larger than 60cm DBH. Note that this figure shows the distribution of sampled trees, which because of the sampling method, is not the same as the distribution of sizes in the forest population. Sampling probability is ostensibly proportional to size, so the number of sampled trees in a basal area sweep indicates equal proportions of basal area, not stocking. To avoid potential misinterpretation as stand table the histogram Fig 2a is therefore depicted as cumulative. The results section will later show a tree size distribution as frequency (stocking) per size class, ie like a conventional stand table.

Fig 2b shows that the median stand basal area (SBA) of the plots was between 20 and 25 m^2ha^{-1} More than 70% of the full list of plots had stand basal area between 10 and 29.9 m^2ha^{-1}. Plots in the short list and mapped as multi-aged had a slightly higher frequency in higher basal areas classes. About 9% of the full list of plots (74) had SBA<10. These latter were all Roberts' plots, and are a result of his systematic grid method including points which fell on open ground.

Table 2 : The 15 most common species in 840 uneNSW PNF plots.

% total	Nrecords	SppCode	Common name	Genus & species	Commerciality
16.0%	1470	spg	Spotted Gum	*Corymbia maculata*	1
10.4%	958	pbd	Pink Bloodwood	*Corymbia intermedia*	2
9.7%	894	wmy	Mahogany, white (group)	*Eucalyptus acmenioides or E. umbra*	2
5.3%	489	mmt	Messmate	*Eucalyptus obliqua*	2
5.3%	488	bbt	Blackbutt	*Eucalyptus pilularis*	1
4.1%	381	twd	Tallowwood	*Eucalyptus microcorys*	1
4.1%	375	gyg	Grey Gum	*Eucalyptus propinqua/Eucalyptus punctata*	2
3.9%	359	fok	Forest Oak	*Allocasuarina torulosa*	5
3.6%	328	ibk	Ironbark group	*Eucalyptus spp.*	2
3.5%	323	frg	Forest red Gum	*Eucalyptus tereticornis*	2
3.1%	289	ded	Dead Tree	*Habitat values only*	5
3.0%	276	trp	Turpentine	*Syncarpia glomulifera*	2
3.0%	271	gbx	Grey Box	*Eucalyptus moluccana/Eucalyptus dawsonii*	2
2.9%	269	bbx	Brush Box	*Lophostemon confertus*	2
2.5%	228	gib	Grey Ironbark	*Eucalyptus siderophloia/Eucalyptus paniculata*	2

49 tree species were recorded from the plots. Half the total tree records were comprised of just 6 species, two-thirds from 10 species, and more than 80% from 15 species (Table 2).

Most of the common species were grouped for commercial assessment in class 1 (high value, well accepted) or class 2 (lesser value but still commercially saleable for sawlog). Classes 3 to 5 are steps from minor or craft uses to non-saleable species.

Methods

All of the plots were measured with the same basic method, viz a basal area point sweep. Sweep plots were used because they are more efficient than fixed area plots for capturing a representative number of larger trees, and provides a more accurate estimate of stand basal area. However fixed area plots may be a more reliable measure of stocking. Hence basal area is used as the primary descriptor for stand density in this report.

For all plots from the first three sources the following measures were recorded for each tree "in" :- species, DBH, crown vigour, bole length (above ground), stump height above ground if non-standard (eg defect such as basal scar), visual log grade for main bole (product potential), and visible habitat attributes if present (hollows, glider scratches etc). Site height was measured or estimated as the mean of two tallest trees in or near the plot. GPS Lat/Long locations were recorded to best instrument accuracy (usually +/- <8m) and these were entered into GIS software (Manifold) for the purpose of map display and assigning the plot to Forest Type, Site Quality and API age class.

The results will show analyses using the following variables;

Site height and SQ:

Site height was not measured in all plots, was not necessarily an estimate of mature canopy height, and in many cases height was estimated by eye. As such, the field records of height may often underestimate potential mature height. Therefore two additional measures have been supplied as better indicators of potential long term tree height and site productivity.

- **SQ** this is an estimate of the maximum basal area (m2/ha) that can be attained in a fully stocked mature healthy native forest on the site. The method is based on an algorithm using monthly climate, soil and landscape variables. (Jay 2013).
- **AusNPP** Net Primary Productivity (refs: Kesteven, Landsberg, and AGO)

These measures were recorded for each plot based on its Lat/Long co-ordinates using climate data for the location. SQ includes soil and topographic factors which are not present in AusNPP. Resolution of SQ is ~25m per pixel, and AusNPP ~250m per pixel.

Basal area (BA) and Canopy BA

Basal area is simply the count of all trees "in" the sweep, multiplied by the instrument factor. In nearly all cases, the instrument used was a glass prism with basal area factor (BAF) =2 m^2ha^{-1}. For 15 plots in one property location, a BAF of 1.125 was used (prism lost during survey ; BCFScomm plots at Rappville NSW).

In the initial stages of data preparation and analysis, before the API map polygons were available, it was anticipated that a crown-adjusted measure of tree basal area (canopy BA) might be more closely linked to the density and diameter of tree crowns when viewed from overhead. The method was originally devised to estimate impact of tree crown size and density on regeneration. (Jay 2013). It was reasoned that if the map polygons showed some relationship to within-stand basal area distribution, the relationship might be even stronger with a canopy-adjusted BA. The rationale for the adjustment is that when a dominant (D) tree occurs near a suppressed tree (S) with the same basal area (diameter), the D tree will have a relatively larger crown spread and leaf area. The method assumes larger radius, more leaf-dense canopies for dominant trees, with relative size and density peaking at a DBH of about 45cm. Canopy BA was calculated for all plots in the short list for the total stand, and for components <40cm DBH and >=40cm DBH. In the end the measure did not add value to the API analysis, so it is not discussed further here.

<u>Stocking</u>

Stocking is a derived measure, using the BAF and tree diameter. Since each tree "in" represents BAF m2/ha (eg BAF=2) in the plot total stand basal area (SBA), the stocking number of trees per ha (Ntpha) is calculated as BAF/tBA where tBA is the tree Basal Area (m2).

<u>Crown vigour</u> : a combination of canopy position and leaf mass

S	Suppressed	weak thin crowns, mostly overtopped, dead or dying tips and lower branches. no direct overhead light, incapable of responding to release. May include large senescent or decrepit trees
I	Intermediate	sparse or one-sided crowns, some sidelight but generally overtopped and likely to have very much reduced growth rates without release; may respond to release, but not always. Include large trees with sparse or weakened crowns.
C	Co-dominant	some sidelight restriction reducing crown depth but full overhead light; capable of further growth despite competing neighbours but may become overtopped in longer term; certainly capable of positive response to release.
D	Dominant	large leaf area and full deep crown, full overhead and plenty of sidelight, strong current growth potential regardless of whether surroundings are thinned, will suppress surrounding smaller trees

<u>Log grades</u> :

Log grades are recorded as potential in the field, and irrespective of species and DBH. The inventory software later applies grade standards such as species acceptance, minimum log length or diameter to screen out actual from potential. Some downgrade is expected due to hidden defect etc. Only the most valuable butt log is recorded to; upper bole logs may add some additional volume but are usually of lesser grade and diameter. For this analysis, the highest grades have been combined as "QPV".

V	Veneer Log	if poles are too large DBH for Length specs, they will automatically
P	Pole	be classed as V, if too small they become Q (else Z etc)
Q	Quota	high quality sawlog: straight clean boles, no major defect
Z	Salvage	low quality sawlog, millable but defective (knots, sweeps, kinks, gum pockets etc)
W	Woodchip (fence)	include potential fencing material in this category
U	Unmerchantable	no saleable use
T	Thinning	small Q or Z logs are automatically identified for stumpage purposes by the inventory software; hence not coded on field data sheets

Stand structure and API

Stand structure is depicted as the sum of basal area at each point in 7 size classes, viz. 15cm DBH class intervals commencing at 10, 25, 40, 55, 70, 85, 100 cm.

The structures were grouped and compared to recent aerial photo interpretation (API) mapping which assigned map polygons to one of two classes; even-aged or multi-aged. This API stratification used crown shape and size to determine whether the trees in polygons of at least 25 ha were predominantly regrowth, mature, or senescing. Subsequently the polygons (or parts thereof) were also classed as even- or uneven-aged. The primary strata of regrowth, mature or senescing were not available for analysis.

The structure of plots was classified using Clustan software (www.clustan.com) and a hierarchical agglomerative method based on minimising variance between groups of plots. The method creates progressively larger clusters of plots of increasing dissimilarity. Results are presented in a tree diagram or 'dendrogram', showing relationship between groups and all plots in the data. The plots were then ordinated in the dendrogram along an axis of similarity.

Figure 3 shows the full horizontal extent of the dissimilarity dendrogram for the full list of plots. Later the same diagram is used truncated to show only the 6 yellow clusters at left the same horizontal scale but greatly expanded vertical scale for clarity. The distance along the horizontal axis represents the dissimilarity between clusters. Numbering from the top down, 1-6, it can be seen for example that clusters 1,2,3,4 form a broad group, and clusters 5 and 6 are more dissimilar than any of the first four.

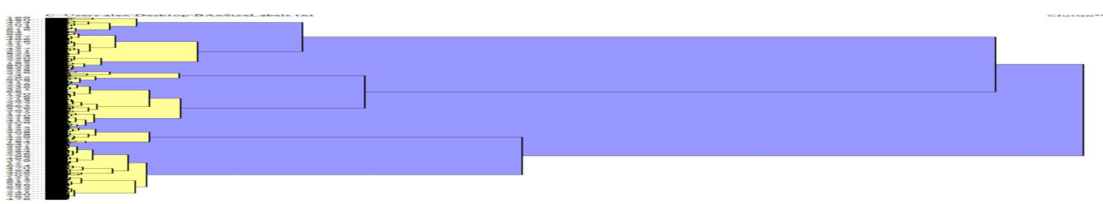


Figure 3 : Cluster dendrogram for 840 uneNSW PNF plots, at the same horizontal scale shown later in Fig 3

The cluster dendrogram was then aligned with the API mapping class for each plot, which provides a rapid visual method to detect any pattern or correlation between class and plot structures.

The condition of plots was further explored using principal components analysis (PCA) with the MVSP software package (www.kovcomp.co.uk/mvsp). PCA is a method for sequentially extracting the principal axes (vectors) of a set of multi-variate data, such that each succeeding axis is orthogonal to a preceding axis and explains the maximum variance in the data. A weighting is calculated for each variable for each axis, and each case (ie plot) in the data is given a score for the axis which is calculated as variable value x weighting. Ordinating (arranging) the plots along the principal axes (components) using the plot's score illustrates the differences between plots using the variables which provide greatest explanatory power.

For PCA analysis, only the shortlist of plots was used (n=214) , and a limited set of 13 variables. The variables were :-

- API mapped age class, even-aged or multi-aged
- plot SBA in each of 7 diameter classes 10,25,40,55 etc, ie the variables used for structure grouping,
- plot SBA for large trees (DBH>=40) in 2 Crown Vigour classes, viz. suppressed and intermediate (S&I), Codominant and Dominant (C&D),
- plot SBA for large trees (DBH>=40) in 3 product classes , viz high grade = quota, pole and veneer (QPV), low grade = salvage and woodchip, (Z&W), and unmerchantable (U).

Two PCA analyses were conducted; one with the API age class weighted x10 (even aged =10, multi-aged =20), and another with minimal but orthogonal separation of API (ie even aged =-1, multi-aged =+1). The 10x weighting was designed to force separation of the plots along an axis dominated by the API class, and see if there were other variables which appeared to also be significant in that axis and/or if the data separated differently on subsequent axes, ie to test if API mapped plots had objectively discernible differences for some important variables.

Results & Discussion

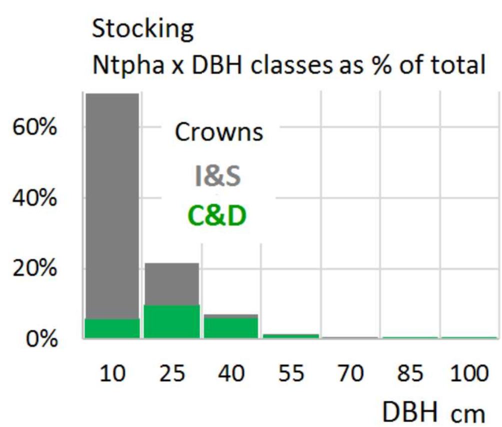
Plot summary data and other details, but not individual tree data, are provided in an accompanying spreadsheet. The exact plot locations are blurred to nearest two decimal places to protect landowner's privacy.

The basal area (and thus number) of small trees in these PNF stands is high if compared to a "normal" sustained yield forest which would have approximately equal basal area and increment in different size classes. This is unlikely to be a sampling artefact given the large number of plots and use of basal area sweep method which avoids the bias of circular plots in under-sampling for large trees.

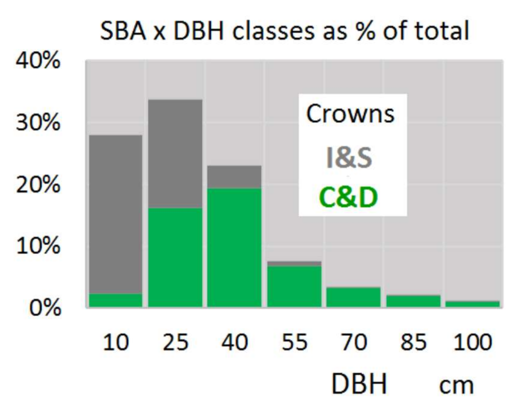
Using those plots with complete Crown and Log Grade records (n=454, excl all anu_SimonR), the % in the total data for stocking and basal area in seven DBH classes is shown in Figure 4 segregated by crown vigour class. DBH class 10 means 10 is the minimum size, and thus it contains trees with DBH 10-24.9cm. Note that, by number, a very large proportion of trees in the PNF plots have small diameters and weak crowns. The disproportion is less when considered by basal area, however it is still the case that a large proportion (44%) of the basal area (and thus volume and biomass) is in small non-vigorous trees less than 40cm DBH. However the majority of the larger trees have strong crowns. Assuming the plots are representative of the whole PNF estate, about one-third (32%) of the forest basal area is in trees with strong crowns >=40cm DBH, and most of that (19%) is in the size class 40-54.9 cm DBH.

Figure 4 Crown vigour and tree size

a. Stocking distribution in seven DBH size classes. Ntpha is calculated from BA and DBH as described in Methods section. The tree count Ntpha in different sizes was summed for all plots, and the % of total stocking count is shown in the graph.



b. Stand basal area distribution in seven DBH size classes. The basal area in different sizes was summed for all plots, and the % of total is shown in the graph



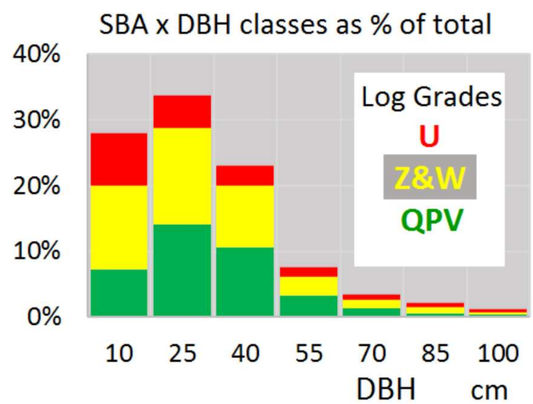
There is a similar proportion of both log grades and species commerciality in all size classes (Fig 5). High grade logs and high value commercial species both comprise less than one third of the whole estate. Note the total basal area in each size class in Fig 5 coincides with Fig 4b.

The most valuable species are Group 1 (cf Table 2). Log grades are described in the Methods section.

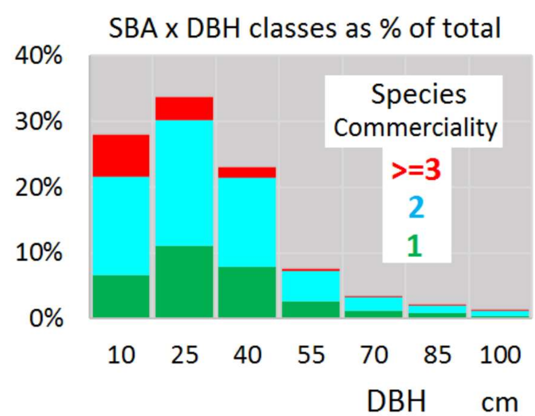
Figure 5

Log Grade and Species commerciality by tree size.

a. Log grade distribution by basal area in seven DBH size classes. The basal area of each Log Grade in different sizes was summed for all plots, and the % of total is shown in the graph.



b. Species commerciality distribution by basal area in seven DBH size classes. The basal area of each species group in different sizes was summed for all plots, and the % of total is shown in the graph



Distribution of log grades within species groups is not shown, however filtering out the non-commercial species made essentially no difference to the patterns and proportions shown in Fig 6 and Table 3.

Figure 6 shows the bole lengths in the forest, segregated by small and large DBH size (Fig 6a and 6b). Within each size class, the proportion across all plots of basal areas of trees in crown vigour classes is shown in major groups L→R; crown = D, C, I, S, separated by the grey arrows. Within each crown vigour class, there are four subgroups of log grades, tagged by colour. The vertical axis shows Bole length (metres), arranged in decreasing bole length order within each Crown and Log Grade combination.

The horizontal scaling represents the proportion of basal area with a given Crown, Grade and Bole length combination, in the same 454 plots depicted in Figs 4 and 5. These plots contain 2235 tree records DBH <40cm and 3489records DBH >=40cm .

The range and median of bole lengths for the different DBH size, crown vigour and log grades, and can be quickly estimated from Fig 6. For example the median bole length for large diameter dominant crowned high value logs is about 8m.

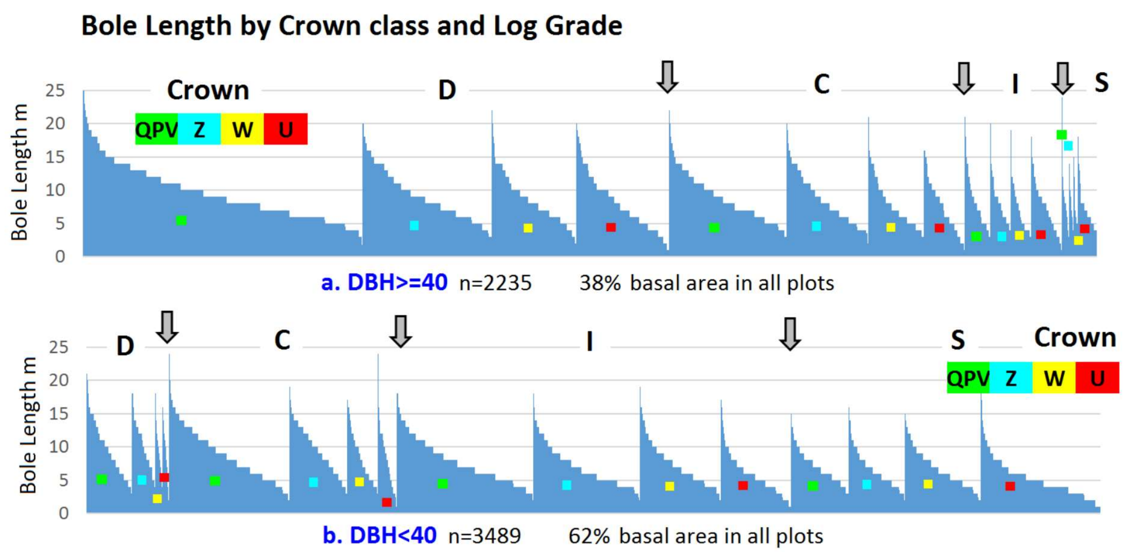


Figure 6 : Proportion of log grades within each crown vigour class for two size classes (a. >=40cm DBH, b. <40cm DBH) , and the distribution of bole lengths within groups.

Table 3 contains a more precise list of basal area proportion of log grades in each crown class, but without the bole length information of Fig 6.

Table 3. Proportion of log grades in each crown class

a. DBH>=40 n=2235 38% basal area in all plots

	Crown	*D*	*C*	*I*	*S*	
Log	QPV	27%	12%	2%	1%	42%
Grade	Z	12%	9%	2%	0%	23%
	W	8%	6%	2%	0%	17%
	U	9%	4%	3%	2%	18%
		57%	30%	10%	3%	

b. DBH<40 n=3489 62% basal area in all plots

	D	*C*	*I*	*S*	
QPV	4%	11%	13%	5%	34%
Z	2%	6%	11%	5%	25%
W	1%	3%	8%	8%	20%
U	1%	2%	7%	12%	21%
	8%	22%	40%	31%	

Large trees with high value logs and vigorous crowns comprise some 15% of the estate SBA [(27%+12%) x 38%]

Figure 7 also displays crown and log grade data, but in this case each plot is shown

By arranging the plot data in two different ways, it can be seen that any correlation between crown vigour and log grade at the plot level is also tenuous at best, and probably non-existent.

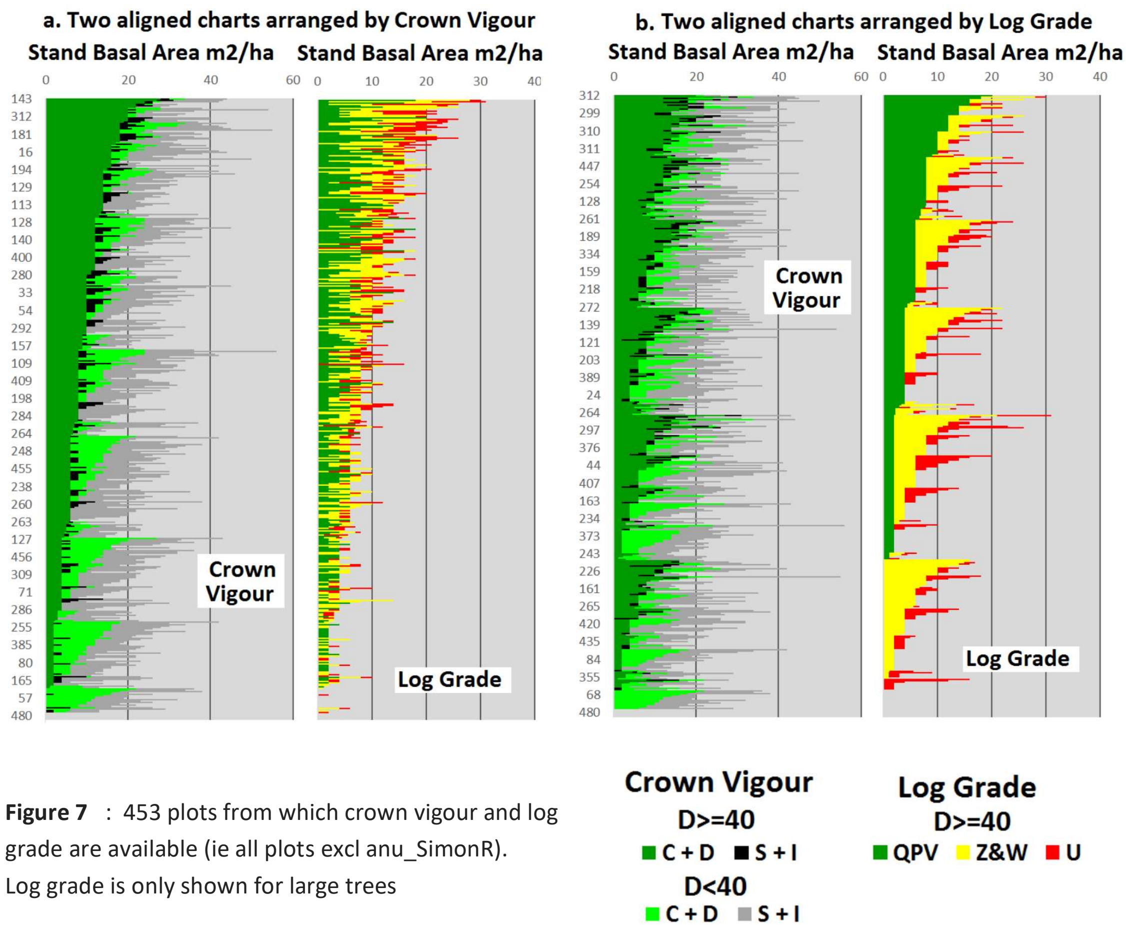


Figure 7 : 453 plots from which crown vigour and log grade are available (ie all plots excl anu_SimonR). Log grade is only shown for large trees

a. a pair of charts in which the LHS is arranged in descending crown vigour order.
b. a pair of charts in which the RHS is arranged in plot SBA with descending order of Log Grade.

Fig 7b shows that very few plots have BA >10m2/ha with large high grade logs, more than 70% of plots have <6m2/ha (3 trees in typical sweep) with large diameter, high grade logs. Some proportion of that will also be in non-commercial species. Around half of measured plots (n=222) had BA<2 m2/ha of high quality large logs, but many in this subset still had high total basal area (BA range 8-56, median 22).

Similarly Fig 7a shows that plots with >15m2/ha of large trees with vigorous crowns comprise about 20% of the estate. Around half of measured plots had <10m2/ha of large trees with vigourous crowns.

Only a few plots actually have a high proportion of large trees, and there does not appear to be any relationship between proportion of large trees and API mapping classes. (Fig 8).

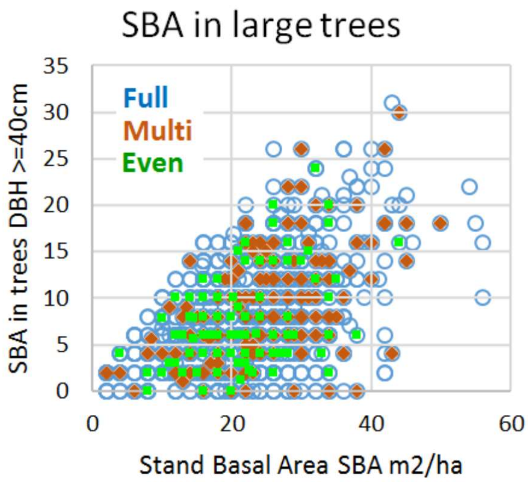


Figure 8 : Proportion of stand basal areas in trees with DBH >=40cm, for the full list of plots n=840, and for plots classed as even aged or multi aged by API mapping.

Site height and AusNPP were not correlated with SQ (Fig 9a), or with each other (Fig 9b). Site height in the 351 plots which had a height record, ranged from 16 to 45m tree height.

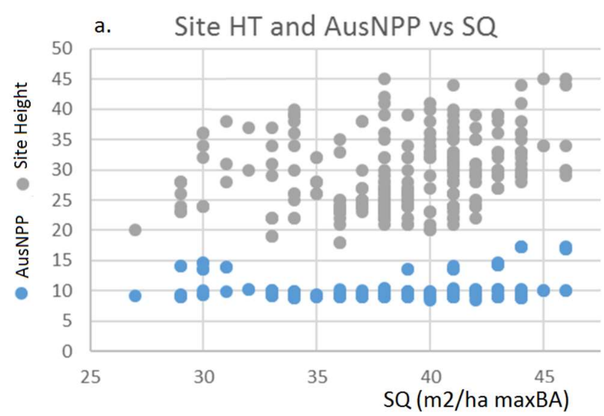
The distribution of SQ for all plots (Fig 9c, excl some from the full list outside of the uneNSW zone) appeared Normal, ranging from 26 to 52, with median SQ about 40.

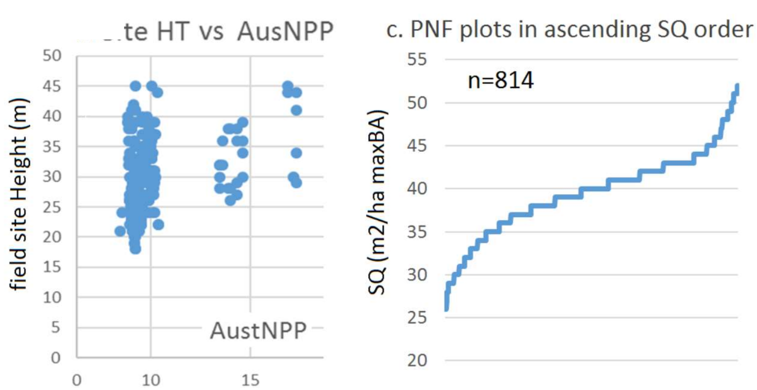
Figure 9

a. Site height and AusNPP compered to SQ. n=351

b. Site height vs AusNPP; n=351.

c. PNF plots arranged in ascending SQ order; n= 814





The results of the clustering method and comparison with stand structures and API classes is shown in Figure 10. The plots have been arranged into 6 distinct groups as first shown in Figure 3. In some cases sub-groups within the main groups can be detected by looking jointly at the dendrogram and adjoining structure diagram.

A description of the attributes of plots within each group is in Table 4, followed by a breakdown of plot occurrence by forest type and API class.

A notable element of Table 4 is the large number of Spotted Gum (SPG) plots which have been identified as “even-aged” in groups 4 and 6 (yellow highlights). However, in looking at Fig 10, it does not appear that structure groups 4 or 6 ought to contain larger numbers of even aged plots; it might have been more expected that groups 1, 2 and 3 would show as having a predominance of even ages (even sizes). However, Table 4b shows that groups 1,2 and 3 do not have a greater quantity of even-aged API mapping plots. Figure 9 suggests that the API mapped classes are in fact randomly associated with forest structures. Perhaps the SPG crowns when viewed on aerial photos have a relatively consistent size and density regardless of DBH, in comparison to other forest types.

Table 4b shows that API classes are well distributed across all sampled forest types.

Similarly, Table 4b and the left side of Figure 10 show that the API mapping class does not appear related to stand structure as sampled at the plot level.

An explanation for the absence of a relationship between the API mapping of forest stands (minimum patch size of 25 hectares) and stand structure at the plot level was not determined as it was beyond the scope of this report. Analysis of the primary strata used by the API mappers for classifying forest as either even-aged or multi-aged forest (being the percentage mix of regrowth, mature and senescing trees) may have helped to explain why there was no relationship. It may be postulated that the large difference in scale between the variable radius inventory plots (say 0.15 of a hectare on average) and the API mapped polygons (25 hectares or greater) was a contributing factor."

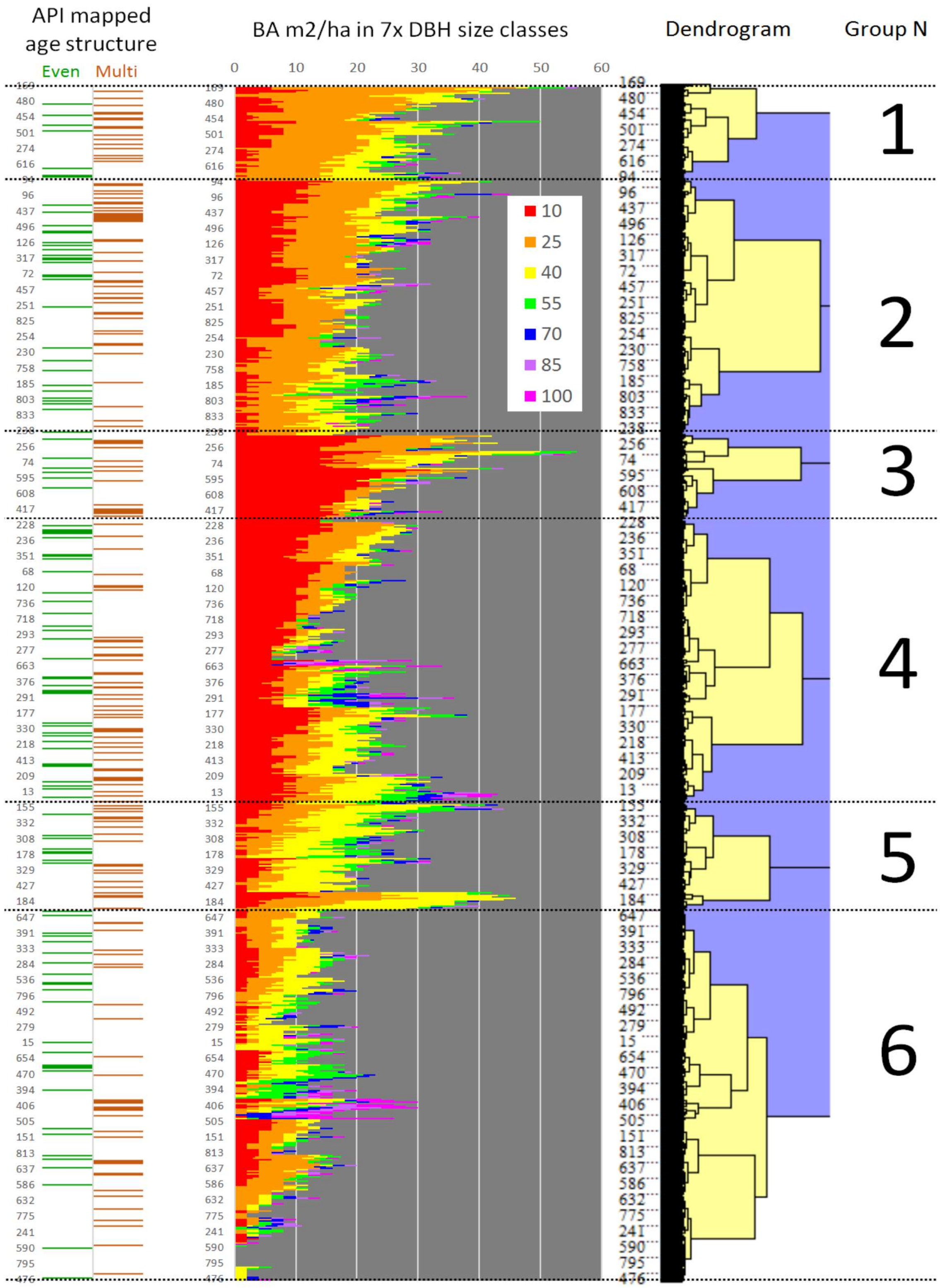


Figure 10 : Cluster groups 1-6 , for dendrogram (right) aligned with API classes (left) and stand structure diagrams (centre). The 840 plots are ordinated top to bottom to match the dendrogram. The stand structure diagram shows plot BA in DBH classes, where class intervals commence at 10, 25, 40, 55, 70, 85, 100 cm as per colours. Gaps in the API class diagram are where plots fell outside the mapped polygons. Numbers on the vertical axes refer to plot_IDs numbered 8-847 in the accompanying spreadsheet. Only every 11th plot is numbered.

Table 4 : a. Cluster group attributes and description

Group 1 : plots with most of the basal area in size class 25-40cm DBH, and few or no very large trees.

Group 2 : plots with most of the basal area in size class 25-40cm DBH, and several larger trees. Two subgroups are (a) plots with generally >8 m2/ha basal area in smallest trees and around 20m2/ha in first two size classes, and (b) plots with low total basal area, generally <6m2/ha in small trees, and at least a few large or very large trees.

Group 3 : plots with highest amount of smallest trees <25cm DBH, a subgroup being those stands with almost all small trees.

Group 4 : a large group with generally low amounts of basal area in the 25 and 40cm classes (25-55cm), but usually >8m2/ha in smallest sizes, and at least a few large or very large trees.

Group 5 : a small group which has most basal area in the 40-55cm DBH classes, low amounts of basal area in the 10-40cm classes, and except for a small subgroup, a few large or very large trees.

Group 6 : a large collection of plots with low basal area (mostly less than 20 m2/ha), low amounts of small trees, and plus or minus some very large trees.

b. distribution by forest type and API mapping class

			Structural Group number											
	ALL	ALL	1	1	2	2	3	3	4	4	5	5	6	6
Forest type	Even	Multi	Even	Multi	Even	Multi	Even	Multi	Even	Multi	Even	Multi	Even	Multi
mBBT	3	16	1	2	2	5	-	2	-	4	-	-	-	3
dBBT	16	31	1	5	4	7	1	1	5	9	1	4	4	5
FLG	-	2	-	-	-	-	-	-	-	1	-	1	-	-
BBX	-	3	-	-	-	1	-	-	-	-	-	2	-	-
MCE	-	11	-	-	-	1	-	2	-	2	-	2	-	4
smTDE	18	20	2	5	7	5	2	2	3	3	3	3	1	2
mSPG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SPG	71	40	3	1	13	11	3	5	26	8	4	2	22	13
DSW	-	33	-	3	-	7	-	1	-	14	-	4	-	4
TEM	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TED	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TSB	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NPT	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rf	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OTH	-	3	-	-	-	1	-	1	-	-	-	1	-	-
#N/A	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Full List	108	159	7	16	26	38	6	14	34	41	8	19	27	31
Short List	81	133	7	15	24	34	4	13	23	32	8	18	15	21

To further test that this conclusion about lack of correlation between API class and stand structure was reasonable, I tried manually ordinating the stand structure diagrams in various ways and comparing these with API class distributions. Four of these are shown below in Fig 11.

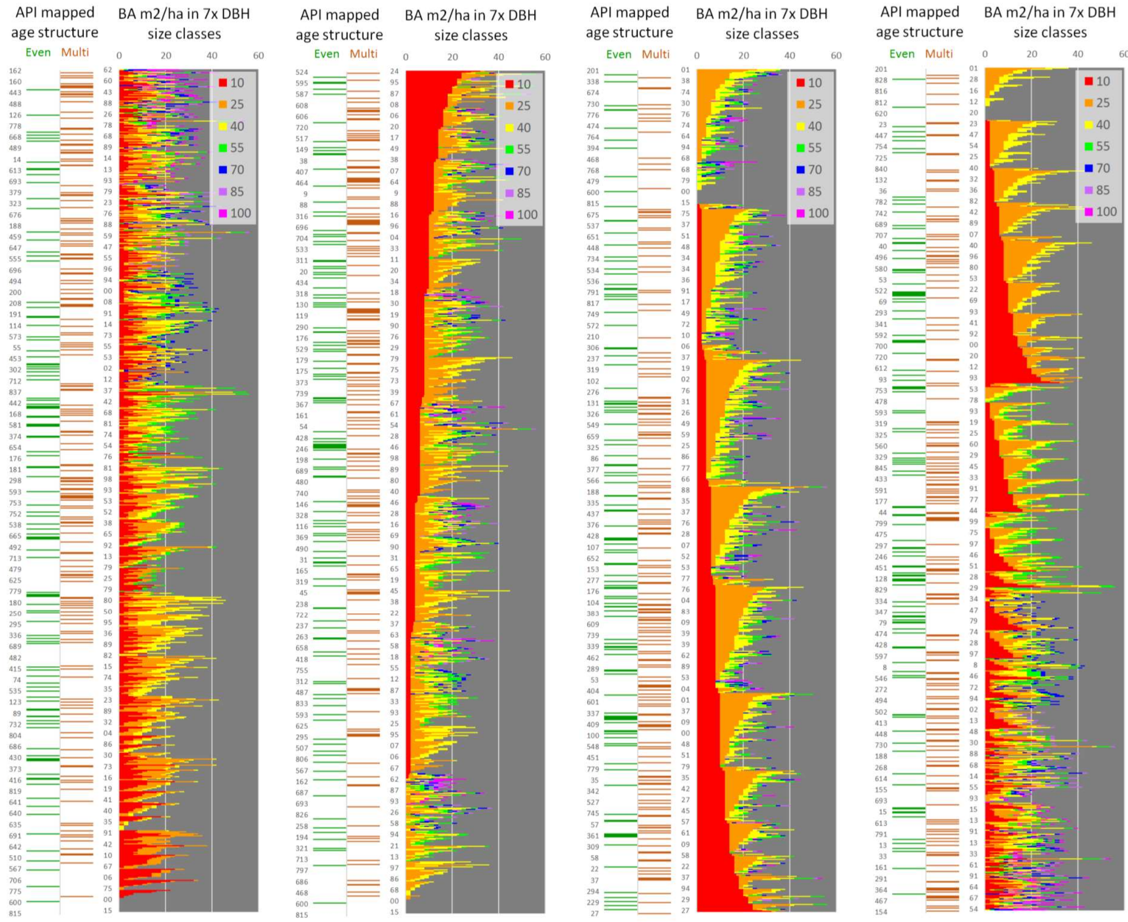


Figure 11 a, b, c, d (L-->R) : Manually ordinated stand structure diagrams and associated distribution of API mapping classes. The plots are arranged vertically as follows:-

a. Descending order of basal area, in descending order of the seven DBH size classes, ie the plot(s) at the very top of the chart have the largest amount of SBA in each DBH size class, and at the bottom of the page are the plots with lowest basal area and only in smallest trees.

b. as per a., but then re-arranged by descending order of smallest tree basal area. The top of the group at the bottom part of the chart with no red (smallest trees) therefore still has the plots with greatest quantity of largest trees first.

c. given that the two smallest size classes were predominant in many of the plots, I tried arranging these in ascending order of smallest, and descending order of next smallest size class, keeping the biggest trees in original descending order.

d. is similar to c. with the next size class also added into the descending order hierarchy

If there was any connection between API mapped age classes and tree size distribution within plots, one would expect some tighter groupings of the API classes in Fig 11, in particular sections of the charts. However this was not found to occur.

The PCA results are shown in Table 5 and Figure 12.

Table 5 : PCA axis results

TEST 1 : API class weighting x10					TEST 2 : API class orthogonal; -1 and +1				
Cum. Percentag	40.615	64.202	75.687	85.385	Cum. Percen	39.768	58.755	74.906	84.756
PCA variable loadings					PCA variable loadings				
	Axis 1	Axis 2	Axis 3	Axis 4		Axis 1	Axis 2	Axis 3	Axis 4
API class	0.979	-0.176	-0.033	-0.057	API class	0.013	0.009	0.018	0.027
10	0.024	-0.262	0.139	0.919	10	-0.239	0.176	0.924	0.235
25	0.007	-0.188	0.897	-0.236	25	-0.176	0.895	-0.254	0.146
40	0.065	0.439	0.28	0.026	40	0.442	0.274	0.004	0.224
55	0.036	0.145	-0.036	0.031	55	0.15	-0.035	0.033	-0.12
70	0.02	0.062	-0.068	0.049	70	0.066	-0.065	0.053	-0.034
85	0.031	0.031	-0.072	0.017	85	0.039	-0.068	0.027	0.054
100	0.024	0.035	-0.047	0.024	100	0.041	-0.044	0.031	-0.038
S&I_D>=40	0.031	0.078	-0.003	-0.002	S&I_D>=40	0.084	-0.002	0.001	0.025
C&D_D>=40	0.145	0.633	0.058	0.15	C&D_D>=40	0.654	0.062	0.148	0.061
QPV	0.065	0.403	0.236	0.245	QPV	0.408	0.235	0.218	-0.593
Z&W	0.078	0.275	-0.148	-0.099	Z&W	0.289	-0.146	-0.079	0.704
U	0.033	0.033	-0.033	0.002	U	0.041	-0.03	0.01	-0.027

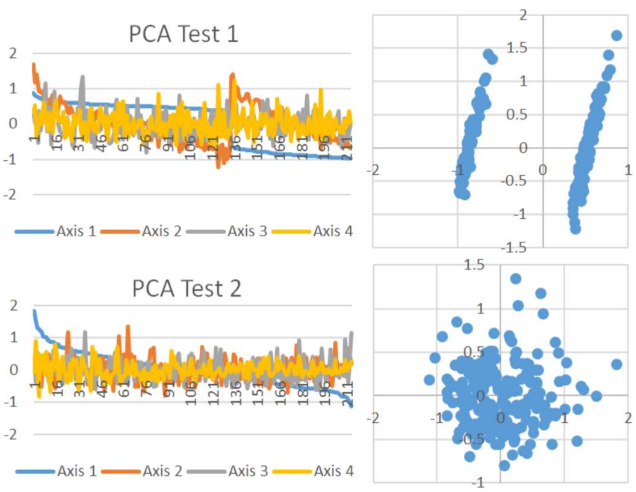


Figure 12:

LHS: Plot scores for 214 short list plots ordinated in descending order, with PCA axis 1 the primary sorting criteria

RHS : Plot scores for 214 short list plots on Axis 1 (x) vs Axis 2 (y)

Yellow highlights in the Table indicate the variable with greatest weighting for determining the plot's position on the axis.

The principal coordinate analysis (PCA) found that when the API class was given 10x weighting (Test1) , it explained 98% of difference between plots along the first axis (Table 5). The first axis in this case explained about 40% of variation in the data, and all other variables on that axis explained less than 8% each for plot differences. The second axis explained another 24% (cumulative 64%) of variation, and the most important distinguishing variable here was the plot's basal area in large trees with vigorous crowns (C&D_D>=40).

In Test2, the API class differences are of minimal importance. The axes compared to Test1 are essentially just shifted up the importance ranking, with little change in either cumulative variance explained by the axis, or in the most important variables and their weightings for the axis.

Fig 12 shows that for Test1, there is an abrupt difference in the axis score (blue line LHS) as would be expected by the forced separation of plots. However, the plot scores for subsequent axes 2, 3, 4 show no correlation with axis 1 scores. Plotting Axis 1 scores against axis 2 (RHS Fig12) shows that on each side of the first axis, the plots are quite evenly spread and across a similar range. Therefore, the API mapped age class is not selecting any differences in condition of plots.

Finally, in Fig 13, the 214 short list plots are shown arranged by descending order of plot basal for crown vigour in large trees (C&D_D>=40) then small trees, and aligned with plot Log grades and API class. Similar information was presented in Fig 7, but Fig 13 contains only the 214 plots which fell within an API mapped age-type polygon.

In Fig 13, there is no discernible pattern in API mapped classes according to crown vigour and log grade distributions.

There appears to be no relationship between API and measured plot characteristics.

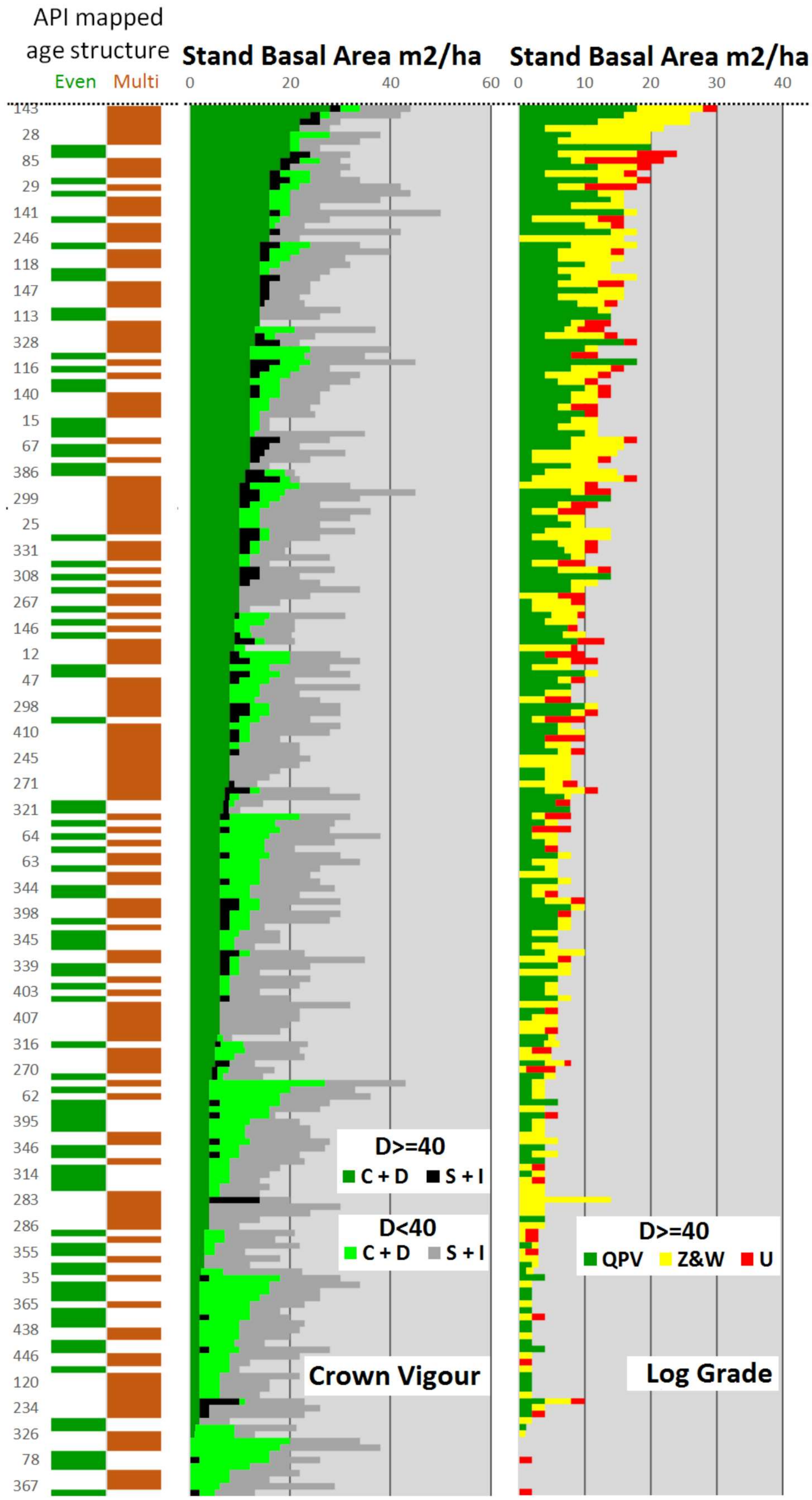


Figure 13 : 214 shortlist plots arranged (centre) by descending order of high crown vigour in large trees (C&D_D>=40), then high crown vigour in small trees (C&D_D<40), then low crown vigour in large and small trees successively. The 214 plots are aligned on LHS with API mapped age classes, and RHS with plot SBA for Log grades in large trees.

Conclusion

Forests in uneNSW PNF are characterised by stands with a predominance of basal area and tree numbers in small size classes (DBH<40cm).

The regrowth is not in good shape. The most common size class on the estate is DBH class 25-40cm which comprises about one-third of total estate basal area. Half of this size class is comprised of trees with weak crowns. The next most abundant size DBH class 10-25cm (28% of estate basal area) has about 90% of the basal area in trees with weak crowns. More than half of the basal area of small trees (of any crown class) is in low quality log grades. However, the proportion of commercial species is reasonably high.

For the estate as a whole, about 15% of the total basal area is comprised of large trees (DBH >=-40cm) with high value logs and vigorous crowns. Most of these are however less than 55cm DBH. The occurrence of this high-quality large volume is not evenly distributed. In fact around half of measured plots had BA<2m2/ha of high quality large logs and more than 80% had BA<8m2/ha of high quality large logs. The estate-wide volume increment in large size high quality logs is therefore likely to be very low.

The current estate structure and condition appears to reflect a long history of “high grading” in PNF. (Jay & Dillon 2016)

Within this project, small scale (minimum patch size of 25 hectares) API Mapping of even-aged versus multi-aged forest, did not show any relationship with stand structure as determined by diameter distributions derived from Basal Area sweeps/Angle count sample plots.

References and further reading

Bauhus, J., McElhinny, C.M. and Alcorn, P. (2002) Stand structure and tree growth in uneven-aged spotted gum (*Corymbia maculata*) forests: some implications for management. *Forestry* **75**, 451-456.

Combe, M., Unwin, G., Dyason, R. and Peacock, R. (1998) Resource profile of "high- graded" dry hardwood forests: implications for improving productivity. In Dyason, R. *et al*. (eds.) *Australian Forest Growers Biennial Conference Proceedings*, Lismore NSW 6-9 July 1998.

Jay, V.A. (2009) *Sustainable Private Native Forestry – Part I. Sustainability index measures on private native forestry sites in northeast NSW: Habitat value and timber productivity; Part II. EUCAMIX: A silvicultural decision support tool for mixed species multi-age private native forestry in northeast NSW.* Rural Industries Research and Development Corporation, Publication No. 09/030, Canberra. https://rirdc.infoservices.com.au/downloads/09-030

Jay V.A. (2013) *EUCAMIX: a mixed-species mixed-age forest growth model for modelling private native forest management and policy outcomes in upper northeast NSW.* Draft PhD thesis chapter excerpts. http://dx.doi.org/10.13140/RG.2.1.4351.6008 **or** **https://www.researchgate.net/publication/279205692**

Jay, V.A., Thompson, D., Macgregor-Skinner, J. and Vanclay, J. (2007a) *Review of the Draft Code of Practice for Private Native Forestry in NSW*. Project PR07.4024. Forest and Wood Products Australia Limited, Melbourne.

Jay, V.A., Nichols, J.D. and Vanclay, J.K. (2007b) Social and ecological issues for private native forestry in north-eastern New South Wales, Australia. *Small-scale Forestry*, **6**, 115-126.

Jay V.A. and Dillon A. (2016) Modelling the outcomes of different silvicultural approaches in the private native forests of north-eastern New South Wales *Australian Forestry* Volume 79, 2016 - Issue 2 pp 85-95 http://dx.doi.org/10.1080/00049158.2015.1123392

Ryan S. and Taylor, D. (2006) *Sustainable Native Forest Management, Case Studies in Managing Private Native Forests in southeast Queensland.* Department of Primary Industries and Fisheries, Brisbane, 121 pp.

Vanclay, J.K. (2007) How to foster good husbandry of private native forests. *Small-scale Forestry*, **6**, 205-218.