Department of Primary Industries
Department of Regional NSW

Forest Yield Association Group Mapping of Private Native Forest, North Coast and South Coast of NSW

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28 October 2023

This report is one of 12 deliverables arising from the NSW Local Land Services Private Native Forests (PNF) research and development program with DPI Forest Science, available at https://www.dpi.nsw.gov.au/forestry/science

More information

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Executive Summary

Forest yield association groups (YAGs) are assemblages of forest types that have common biophysical attributes and common timber properties. In NSW the classification and mapping of forests based on their timber values has been limited to publicly managed State forests. On private land there is no forest type mapping for this purpose. The preparation of forest YAG maps therefore represents a major advance in mapping timber values.

The aims of this study are to:

a) Analyze the relationship between LiDAR, climatic, soil type, sentinel and topographic variables and YAGs

b) Develop a spatially-explicit model (25m resolution) of yield association groups.

c) Produce a map of yield association groups for Private Native Forest, North Coast of NSW

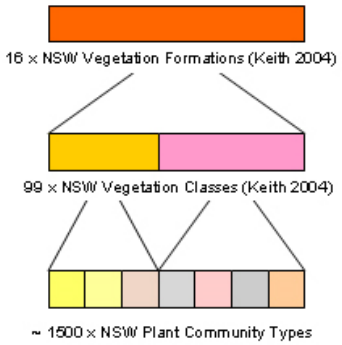
d) Produce a map of yield association groups for Private Native Forest, South Coast of NSW

Key findings of the project:

- The most important variables for the YAG groups were Digital Elevation Model (DEM), followed by sentinel bands b3 and b4, cover and 99th percentile using LiDAR data. The most important bioclimatic variables were Annual Precipitation, Mean Temperature of Warmest Quarter and Mean Temperature of Coldest Quarter. Bulk density and depth of soil were the most important soil variables.
- Using a data mining technique, k Nearest Neighbour (k-NN), a spatially explicit model for yield association groups, was developed at 25m resolution for Private Native Forest, North and South coast of NSW.
- The model for North Coast showed a good agreement with the reference data with an overall accuracy of 80%, 95% confidence interval of 76.0% - 84.0%. Majority of User's and producer's accuracy were in the range of 72.3% to 91.7%.
- The North Coast model was applied to the LiDAR, climatic, soil type, sentinel and topographic variables and a map for the YAGs was produced for Private Native Forest, North Coast of NSW
- The model for South Coast showed a good agreement with the reference data with an overall accuracy of 80%, 95% confidence interval of 78.0% - 82.0%. Majority of User's and producer's accuracy were in the range of over 70% to 100%.
- The South Coast model was applied to the LiDAR, climatic, soil type, sentinel and topographic variables and a map for the YAGs was produced for Private Native Forest, South Coast of NSW

Introduction

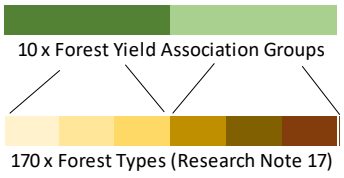
The Department of Environment Planning and Industry (DPIE) has the lead role in vegetation mapping in NSW. DPIE maps vegetation at three levels, the highest being Vegetation Formations, then Vegetation Classes and finally Plant Community Types.



The DPIE Vegetation classification is principally used for biodiversity assessment and conservation planning and has limited application for mapping of timber and other forest values like apiary.

Forests are a form of woody vegetation. To map vegetation as forest the units must conform with the nationally agreed definition being woody vegetation dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding 2 metres and with existing or potential crown cover of overstorey strata about equal to or greater than 20 per cent.

In NSW the classification and mapping of forests based on their timber values has been limited to publicly managed State forests. The Forestry Corporation of NSW has, over a sixty-year period, mapped most State forests according to their 'forest type' (Forestry Commission of NSW, 1965). The agency's forest type classification guide (Research Note No. 17) identifies 170 discrete forest types. In recent years, the Forestry Corporation has grouped its forest types into forest Yield Association Groups (YAGs).



Forest YAG maps are of specific interest to the timber industry and those who manage multiple-use forests. The extent and distribution of YAGs can assist in the planning and management of timber harvesting, roading, controlled burning, grazing, apiary and forest recreation.

On private land there is no forest type mapping of this kind. The preparation of forest YAG maps therefore represents a major advance in mapping timber values.

For this study the native forests of the NSW North Coast were grouped into seven YAGs.

1. Rainforest
2. Viney Scrub

3. Coastal Blackbutt
4. Spotted Gum
5. Coastal Eucalypts
6. Tableland Eucalypts
7. Swamp Sclerophyll

Coastal Blackbutt, Spotted Gum, Mixed Coastal Eucalypts and Tableland Eucalypts were further split into three sub-classes, namely, Tall Moist, Semi-moist and Taller Dry, and Dry Together this approach generated fifteen YAG sub-classes (Table 1)

Table 1. Forest Yield Associations of the NSW North Coast

1. Rainforest	
2. Viney Scrub	
3. Coastal Blackbutt	3.1. Tall Moist
	3.2. Semi-moist and taller dry
	3.3. Dry
4. Spotted Gum	4.1. Tall Moist
	4.2. Semi-moist and taller dry
	4.3. Dry
5. Coastal Eucalypts	5.1. Tall Moist
	5.2. Semi-moist and Taller Dry
	5.3. Dry
6. Tableland Eucalypts	6.1. Tall Moist
	6.2. Semi-moist and taller dry
	6.3. Dry
7. Swamp Sclerophyll	

A complete description of the YAG classification system is presented in Appendix A.

The aims of this study were to:

a) Analyze the relationship between LiDAR, climatic, soil type, sentinel and topographic variables and YAGs

b) Develop a spatially-explicit model (25m resolution) of yield association groups.

c) Produce a map of yield association groups for Private Native Forest, North Coast of NSW

d) Produce a map of yield association groups for Private Native Forest, South Coast of NSW

Data

Reference Data

Observations of overstory species were collected using a combination of existing forest inventory plot data and aerial photo interpretation. Forest inventory plots are ideal for assigning YAG because of collection of trunk diameter for all trees over a fixed area and consequently that ability to calculate Basal Area which is closely corelated with crown area. This allows relative crown cover of different overstory species to be estimated.

Forest Inventory plots were provided by Forestry Corporation of NSW and were authorised for generation of YAG observations. Plot locations were displayed over ADS stereo imagery provided by NSW Spatial Services, and viewed in three-dimensional photogrammetric software, Summit Evolution – Lite Edition 7.4, produced by DAT/EM Systems International. Image histograms were manipulated within the software to optimise differences between species.

Although plots were located with GPS, spatial accuracy is variable due to the range of dates of plot measurement, equipment, terrain, attenuation of the microwave signal by the forest canopy, and, parallax error resulting from view-angle of the sensor, height of the canopy, and projection of plot coordinates on to a digital terrain model. In addition to potential spatial inaccuracy, plot locations may have been harvested or burnt after field measurement. To correct spatial error in plot location, observation areas were shifted where necessary so the proportion of species in the photo-observation matched the measured proportions. Plots where harvesting or fire after measurement could significantly influence spectral reflectance were excluded from analysis.

Predictor Variables

LiDAR Data

The LiDAR data in the LLS project was collected only for a sample of PNF properties. A much more complete LiDAR coverage of the north coast area is available through NSW Spatial Services (https://www.spatial.nsw.gov.au/). 236 individual LiDAR surveys between 2001 and 2015 covering an area in excess of 245,000 square kilometres is available from Spatial Services. Figure 1 is the map of the available data, point density varies from less than 1 point per square meter to 1 or more points per square meter. Five LiDAR variables; average height of the first returns, standard deviation of first returns, cover, 95% percentile height (p95) of first returns and 99% percentile height (p99) of first returns were selected for YAGs modelling.

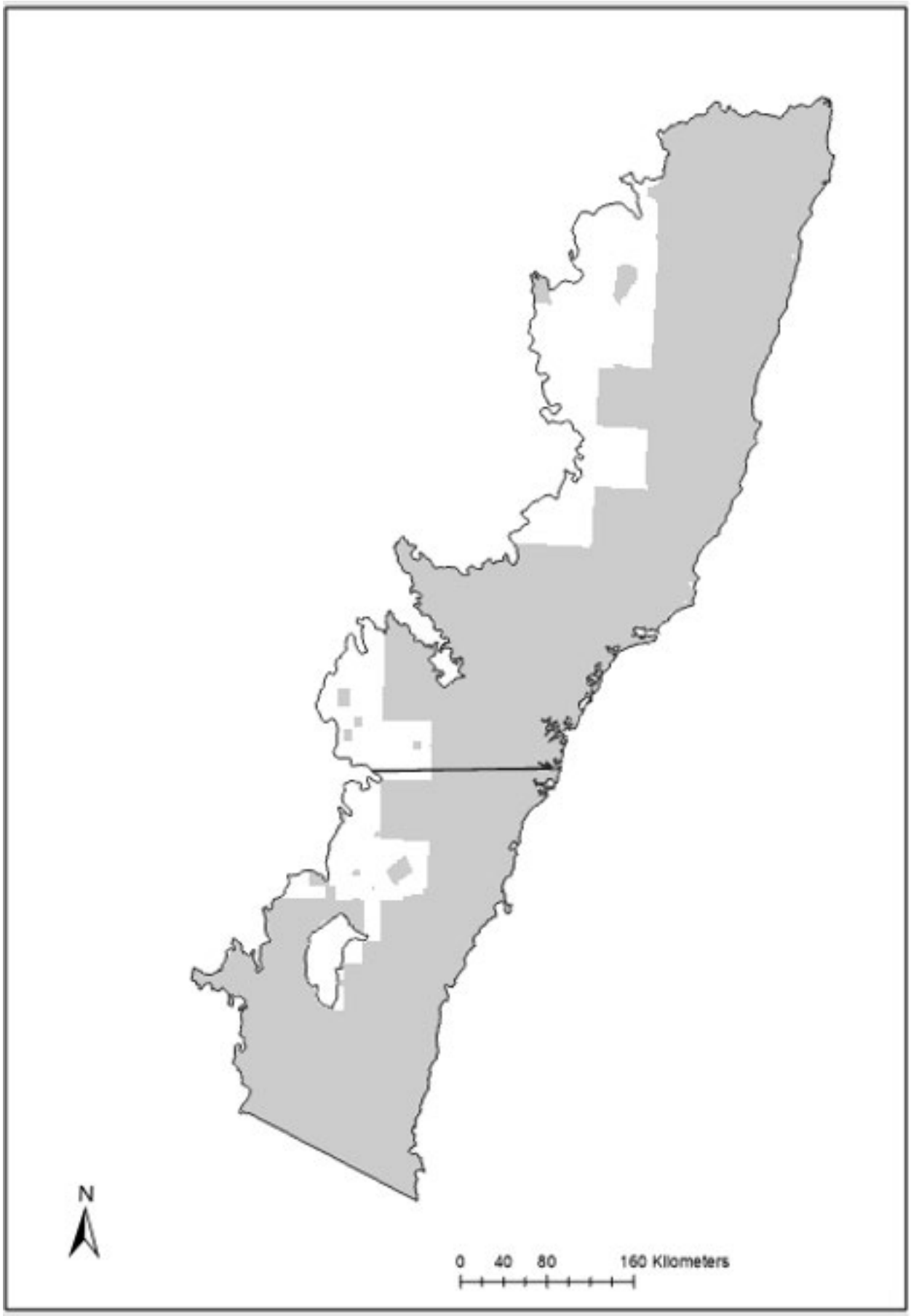


Figure 1: Extent of Spatial Services LiDAR data coverage for North Coast and South Coast of NSW.

Bioclim Data

Bioclimatic variables are derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variables (Worldclim 2021). These are often used in species distribution modeling and related ecological modeling techniques. The bioclimatic variables represent annual trends (e.g., mean annual temperature, annual precipitation) seasonality (e.g., annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters). A quarter is a period of three months (1/4 of the year).

They are coded as follows:

BIO1 = Annual Mean Temperature

BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))

BIO3 = Isothermality (BIO2/BIO7) (×100)

BIO4 = Temperature Seasonality (standard deviation ×100)

BIO5 = Max Temperature of Warmest Month

BIO6 = Min Temperature of Coldest Month

BIO7 = Temperature Annual Range (BIO5-BIO6)

BIO8 = Mean Temperature of Wettest Quarter

BIO9 = Mean Temperature of Driest Quarter

BIO10 = Mean Temperature of Warmest Quarter

BIO11 = Mean Temperature of Coldest Quarter

BIO12 = Annual Precipitation

BIO13 = Precipitation of Wettest Month

BIO14 = Precipitation of Driest Month

BIO15 = Precipitation Seasonality (Coefficient of Variation)

BIO16 = Precipitation of Wettest Quarter

BIO17 = Precipitation of Driest Quarter

BIO18 = Precipitation of Warmest Quarter

BIO19 = Precipitation of Coldest Quarter

Sentinel Data

A set of multispectral, cloud free Sentinel-2 data acquired from mid December 2018 to mid February 2019 was downloaded from the Copernicus Data Hub (https://cophub.copernicus.eu/) . In this study, the Sentinel-2 bands available at 10 m (blue B2: 490 nm, green B3: 560 nm, red B4: 665 nm, NIR B8: 842 nm) and 20 m spatial resolutions (red-edge: B5: 705 nm, B6: 740 nm, B7: 783 nm; narrow NIR B8a: 865 nm, SWIR: B11: 1610 nm and B12: 2190 nm) were used. Vegetation indices Normalized Burn Ratio (NBR) and Normalised difference vegetation index (NDVI) were also calculated. NDVI was further created for three other time periods (March to May 2019, June to August 2019 and September to December 2019) to capture the seasonal difference between YAGs.

Topographic Data

Digital elevation model (DEM) at 25m resolution, layer from FCNSW was used. A number of topographic variables were created using this layer. The variables are; Slope, Aspect, roughness, topographic position index and topographic roughness index.

Soils Data

The soils data was downloaded from Soil and Landscape Grid of Australia (https://www.clw.csiro.au/aclep/soilandlandscapegrid/ProductDetails-SoilAttributes.html). The variables extracted are; Available Water Capacity, Bulk Density, Clay percentage, Depth of Regolith in meters, Depth of Soil in meters, Organic Carbon percentage, pH CaCl2, Sand percentage, Silt percentage, Total Nitrogen percentage and Total Phosphorus percentage.

Methods

k-Nearest Neighbour (k-NN)

k-Nearest Neighbour (k-NN) is a non parametric approach commonly used to integrate sample inventory with remotely sensed data and other geospatial data to produce a model that can be used to predict the response variable for pixels where the response varaibles are not known. This was first introduced to forest inventory practice by Tomppo (1991). Neighbour techniques have been used in forestry for estimation and spatial prediction of forest attributes over large geographic regions (Gjertsen, 2007; Moeur et al., 2011; Ohmann et al., 2011; Tomppo et al., 2008; Wilson, Lister, & Riemann, 2012). In its simplest form the unsampled locations are matched to the most similar sampled locations for which field data exists. The similarity is defined in terms of the feature space, typically measured as Euclidean or Mahalanobis distance between covariates available across the entire area of interest (e.g. remotely sensed data). The k-NN is widely used for estimation of forest attributes using various remote sensing data (Franco-Lopez et al., 2001; McRoberts et al., 2007; Makela & Pekkarinen, 2004; Tatjana et al., 2007).

Random Forest is used as a distance measure for proximity matrix in KNN (Breiman 2001). This matrix has a row and column for every observation (all reference plus target observations). The elements contain the proportion of trees where observations are found in the same terminal nodes. Since every observation is in the same terminal node as itself, the diagonal elements of this matrix have the value 1. Breiman (2001) shows that the proximities are a kind of Euclidean distance between observations and uses them as a basis for imputing missing values to observations (Crookston and Finley 2007). The accuracy of imputation depends on the choice of predictors, explanatory power of auxiliary variables, size and distribution of reference sample, distance or nearness measure, number of neighbours (i.e. value of k), and weight function used for prediction (Ohmann et al., 2011)

Variable Selection Methods

The predictive power of the variables is identified using the variable importance plot (Crookston and Finley, 2007). Gini coefficient is a measure of how each variable contributes to the homogeneity of the nodes and leaves in the resulting random forest. The higher the value of mean decrease Gini score, the higher the importance of the variable in the model. Variables with high importance are drivers of the outcome and their values have a significant impact on the outcome values. By

contrast, variables with low importance might be omitted from a model, making it simpler and faster to fit and predict.

Model Assessment and Validation

Model validation and assessment is an important step in model fitting process. Model validation is the comparison between predicted and observed values, the closer the predicted and observed values the better the model. Internal validation methods which aim to provide a more accurate estimate of model performance for new data that is not used in model building was used. A 10 fold cross validation which is a form of internal validation, was used to validate the final model. In this method data is divided into 10 samples, nine samples are used for model building and the tenth sample is used for evaluation of the model. This is repeated for all the ten samples by leaving the first and then the second sample out and using the rest for the data for model building. All the analysis was done using R statistical package (R Development Core Team, 2020).

Accuracy Assessment

Confusion matrix is the best way to assess the accuracy of a classification model. The matrix compares the actual observed values with those predicted by the fitted model. This gives us a quantitative measure of how well our classification model is performing and what kinds of errors are made. Confusion matrix is a two way table of predicted values along the rows and observed values along the columns. For two classes the table is presented below.

Table 2: Confusion matrix with two classes.

	Observed Values	
Predicted Values	**Commercial**	**Non-Commercial**
Commercial	**True Positive (TP)**	**False Positive (FP)**
Non-Commercial	**False Negative (FN)**	**True Negative (TN)**

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN}$$

For more than two classes, these results are calculated comparing each factor level to the remaining levels (i.e. a "one versus all" approach). In each case, the overall accuracy and Kappa statistic are calculated.

Cohen's kappa coefficient (κ) is a statistic (Cohen, 1960) that measures the agreement between the observed and chance agreement. It reflects the difference between actual agreement and the agreement expected by chance. Kappa of 0.80 means there is 80% better agreement than by chance alone.

Cohen's kappa is

$$\kappa = \frac{(\text{Observed} - \text{chance agreement})}{(1 - \text{chance agreement})}$$

User's accuracy: User's accuracy corresponds to error of commission (inclusion). From the perspective of the user of the classified map, it quantifies the accuracy of the map. It is calculated as: Number of pixels correctly identified in a given map class / Number of pixels claimed to be in that map class. In other words it defines how many of the pixels on the map are actually what they say they are.

Producer's accuracy: From the perspective of the maker of the classified map, how accurate is the map?. It is calculated as the number correctly identified in reference pixels of a given class/ number of pixels are actually in that reference class. This statistic quantifies how many pixels on the map are labelled correctly.

Map Creation

North Coast of NSW

Plot imputation model developed and validated was applied at pixel level with all the predictor variables identified in the model development. The map was then created for the NSW North Coast for areas where all the predictor variables were available. Four YAG groups; Blackbutt, Coastal Eucalypts, Tableland Eucalypts and Spotted Gum further classifies as dry, semi moist and moist based on the Site Index (SI) values. Dry where SI <25m, 25-35m as semi moist and >35m as moist.

South Coast of NSW

For South coast the YAGs were; Coastal Dry, Negligble Productive Types, Tableland Gum-Peppermint, Brown Barrel-Messmate, Silvertop Ash, Alpine Ash, Rainforest, Yellow Stringybark, Spotted Gum and Moist Coastal. The complete description of the YAGs is for the south coast is presented in Appendix C. Non-Eucalypt Forest (also non-rainforest) and Non-Forest were combined with Negligible Timber Value. There were only 11 Blackbutt observations and most of the plots had just 20-30% Blackbutt. The proportion of Blackbutt in south coast is really small and most of it is mixed that's why FCNSW does classify Blackbutt as a YAG for south coast (per comm. Tim Parkes). So, it was excluded as a YAG.

All the analysis was done using R statistical package (R Development Core Team 2020) and ArcGIS Pro.

Results

North Coast of NSW

There were 409 plots in the reference data. Three of those plots did not have a YAG associated with them, 1 plot with paperbark species, 1 with rock/shrubs and another the third with wattle species. One more plot was with missing values. So a total of 405 plots were used for analysis; with 66 plots of Coastal Blackbutt, 143 plots of Coastal Eucalypts, 21 Rain forest, 47 Spotted Gum, 17 Swamp Sclerophylls, 99 Tableland Eucalypts and 12 Viney Scrub. The box plot for all the 56 predictor variables are presented in Appendix B. These plots show how variables distinguish the various YAG classes. The location of reference plots is presented in Figure 2.

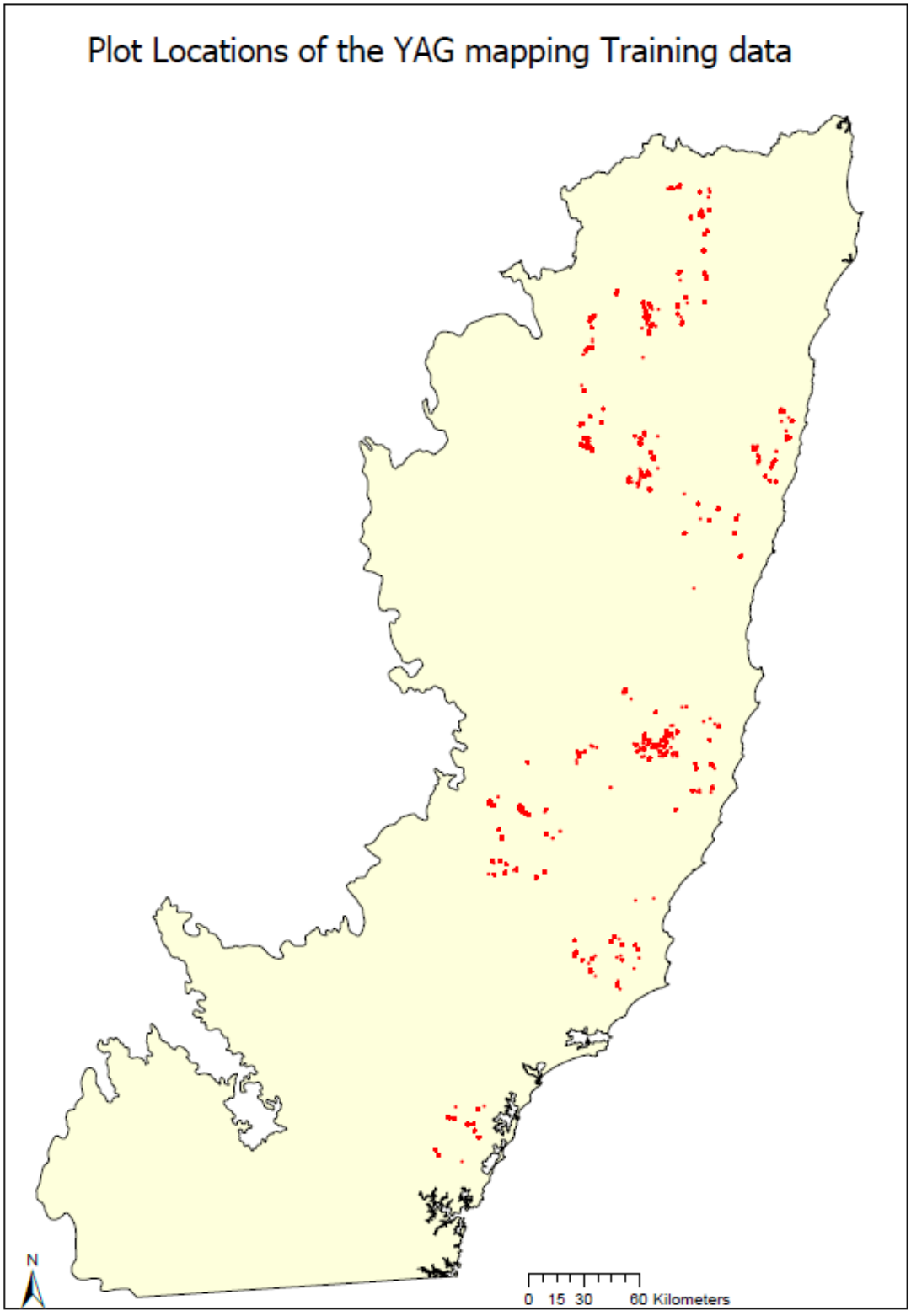


Figure 2: Location of reference plots for North Coast NSW

Model Validation & Accuracy Assessment

The model showed a good agreement with the reference data, an overall accuracy of 80%, 95% confidence interval of 76.0% - 84.0%. The kappa value calculated is 0.74. Landis and Koch (1977) have proposed the following as standards for strength of agreement for the kappa coefficient: 0=poor, .01–.20=slight, .21–.40=fair, .41–.60=moderate, .61–.80=substantial, and .81–1=almost perfect.

So, the agreement between the predicted values from the random forest and reference data is substantial.

The User's and Producer's accuracies are also calculated for each group. A two way table of the predicted values and the actual observed YAG classes is called a confusion matrix and is presented in Table 3. Table 4 presents the accuracies for the seven YAG classes.

Table 3: Confusion matrix for the KNN model fitted using 405 plots for North Coast NSW.

Predicted YAG Class	Actual YAG Class						
	Coastal Blackbutt	Coastal Eucalypts	Rainforest	Spotted Gum	Swamp Sclerophyll	Tableland Eucalypts	Viney Scrub
Coastal Blackbutt	50	8	0	0	4	0	0
Coastal Eucalypts	12	115	5	13	1	7	1
Rainforest	0	3	14	0	0	0	0
Spotted Gum	1	9	1	34	2	0	0
Swamp Sclerophyll	1	0	0	0	9	0	0
Tableland Eucalypts	2	8	0	0	0	92	0
Viney Scrub	0	0	1	0	1	0	11

Table 4: Accuracy assessment of the KNN model for North Coast NSW

YAG Class	User's Accuracy	Producer's Accuracy
Coastal Blackbutt	80.6%	75.8%
Coastal Eucalypts	74.7%	80.4%
Rainforest	82.4%	66.7%
Spotted Gum	72.3%	72.3%
Swamp Sclerophyll	90.0%	52.9%
Tableland Eucalypts	90.2%	92.9%
Viney Scrub	84.6%	91.7%

Yield Association Group Map of Private Native Forest, North Coast of NSW

A total of forty LiDAR, climatic, soil type, sentinel and topographic variables were used as predictor variables to produce a map of YAG groups. The resulting map is presented in figure 3.

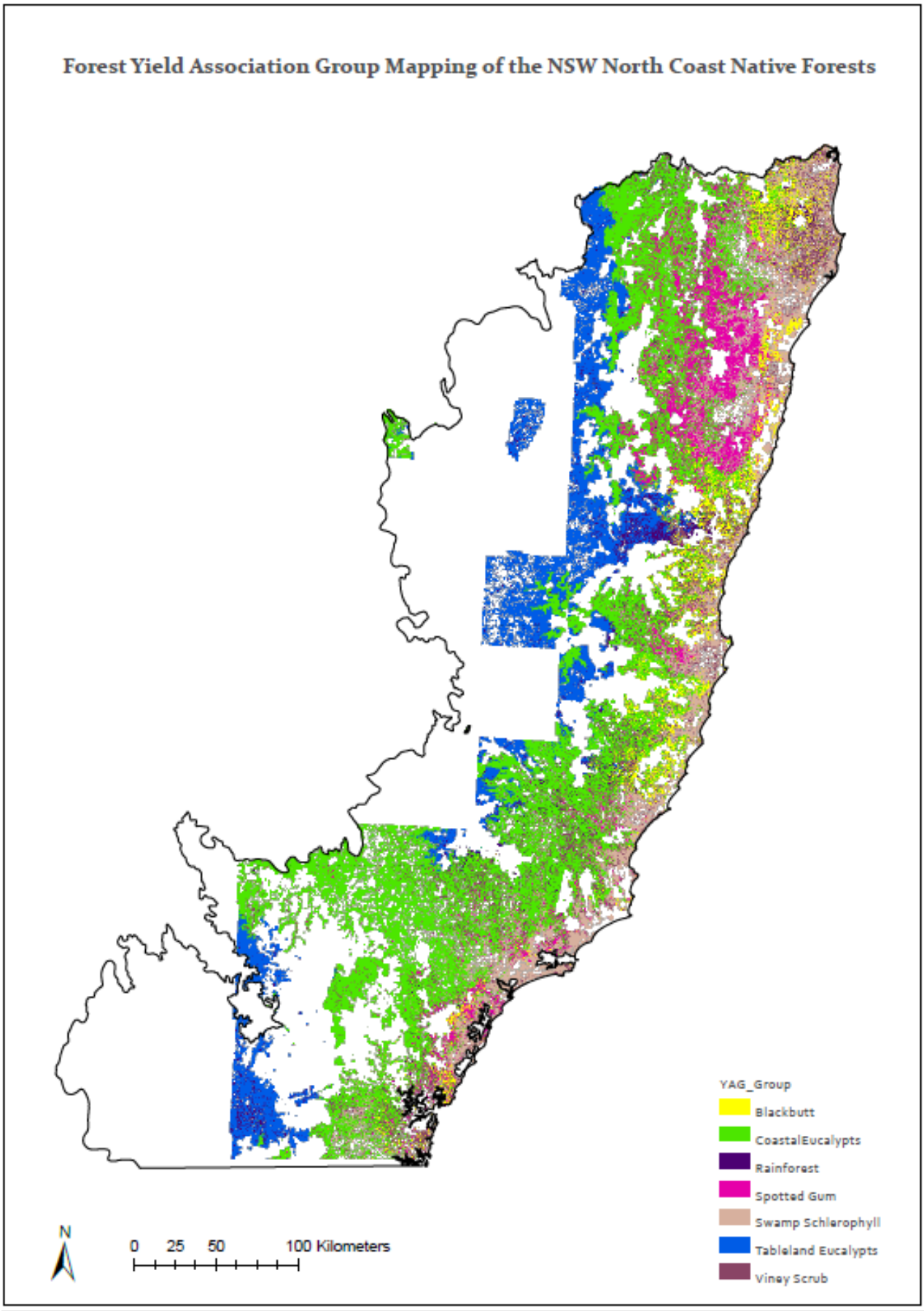


Figure 3: Map of Seven Yield Association Groups for North Coast NSW Private Native Forest.

Four YAG groups; Blackbutt, Coastal Eucalypts, Tableland Eucalypts and Spotted Gum further classifies as dry, semi moist and moist (Figure 4). Figure 5 is the plot of the forest area in hectares for each of the YAGs in private native forest, North Coast of NSW.

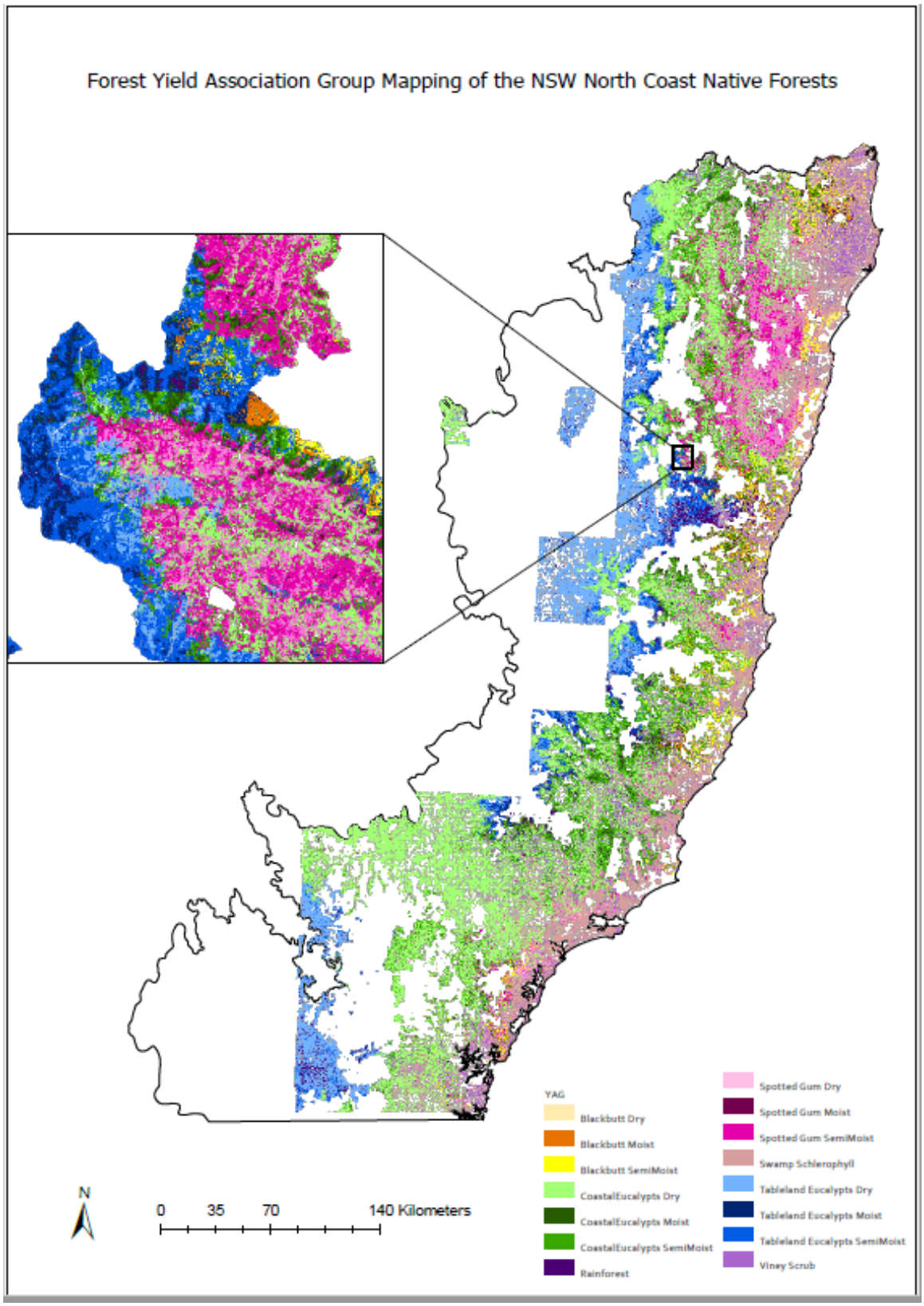


Figure 4: The map with the four Yield Association Groups; Blackbutt, Coastal Eucalypts, Tableland Eucalypts and Spotted Gum further classifies as dry, semi moist and moist.

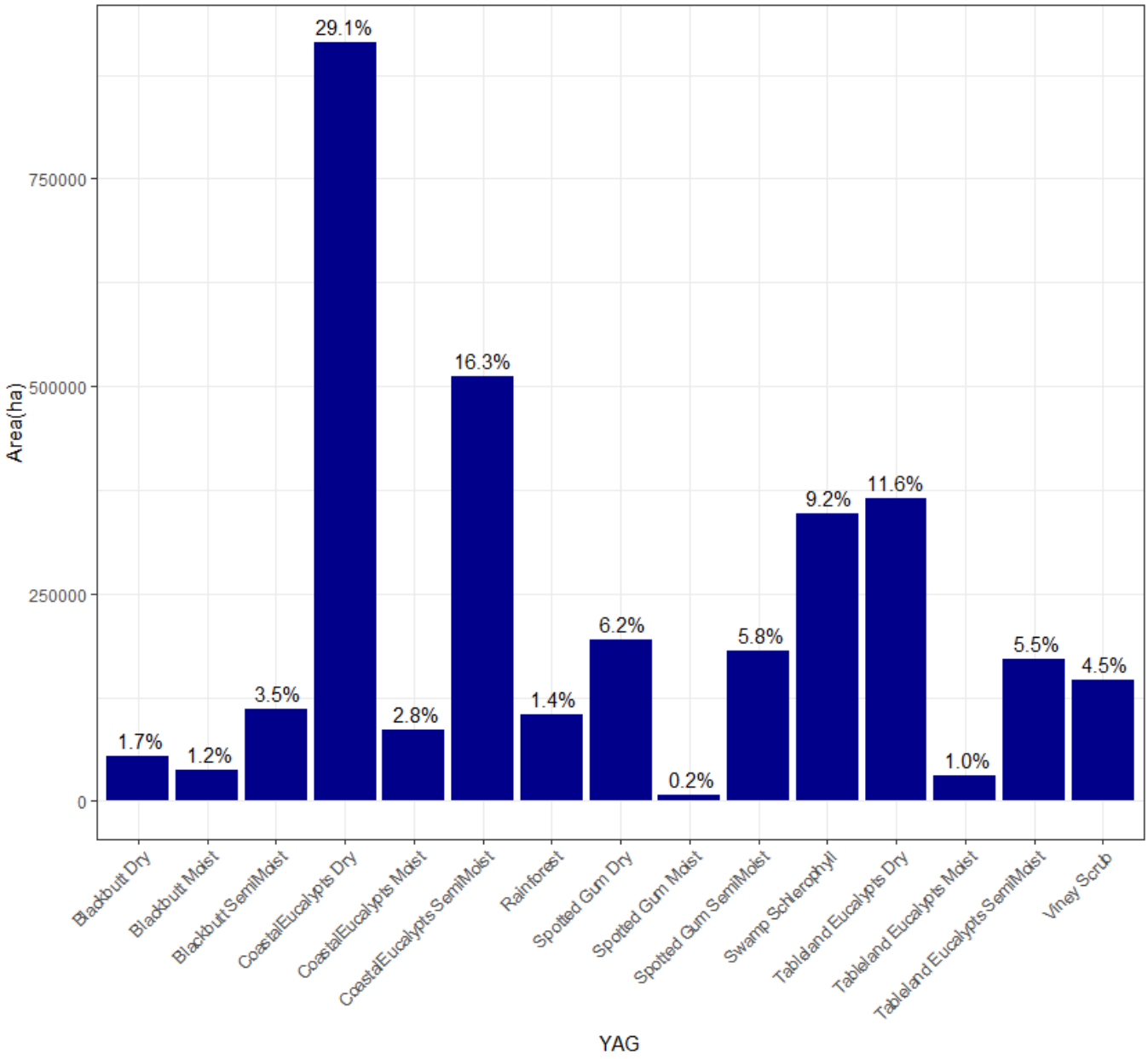


Figure 5: Area under each of the yield association groups in private native forest in North Coast of NSW. The percentage area for each of the YAGs is presented on top of the bars.

South Coast of NSW

There were 1523 plots that were used as reference data for South Coast. Alpine Ash 119, Brown Barrel - Messmate 157, Coastal Dry 224, Moist Coastal 56, Negligible Productive Types 282, Rainforest 36, Silvertop Ash 200, Spotted Gum 146, Tableland Gum - Peppermint 185, Yellow Stringybark Gum 118. The plot locations are presented in Figure 6.

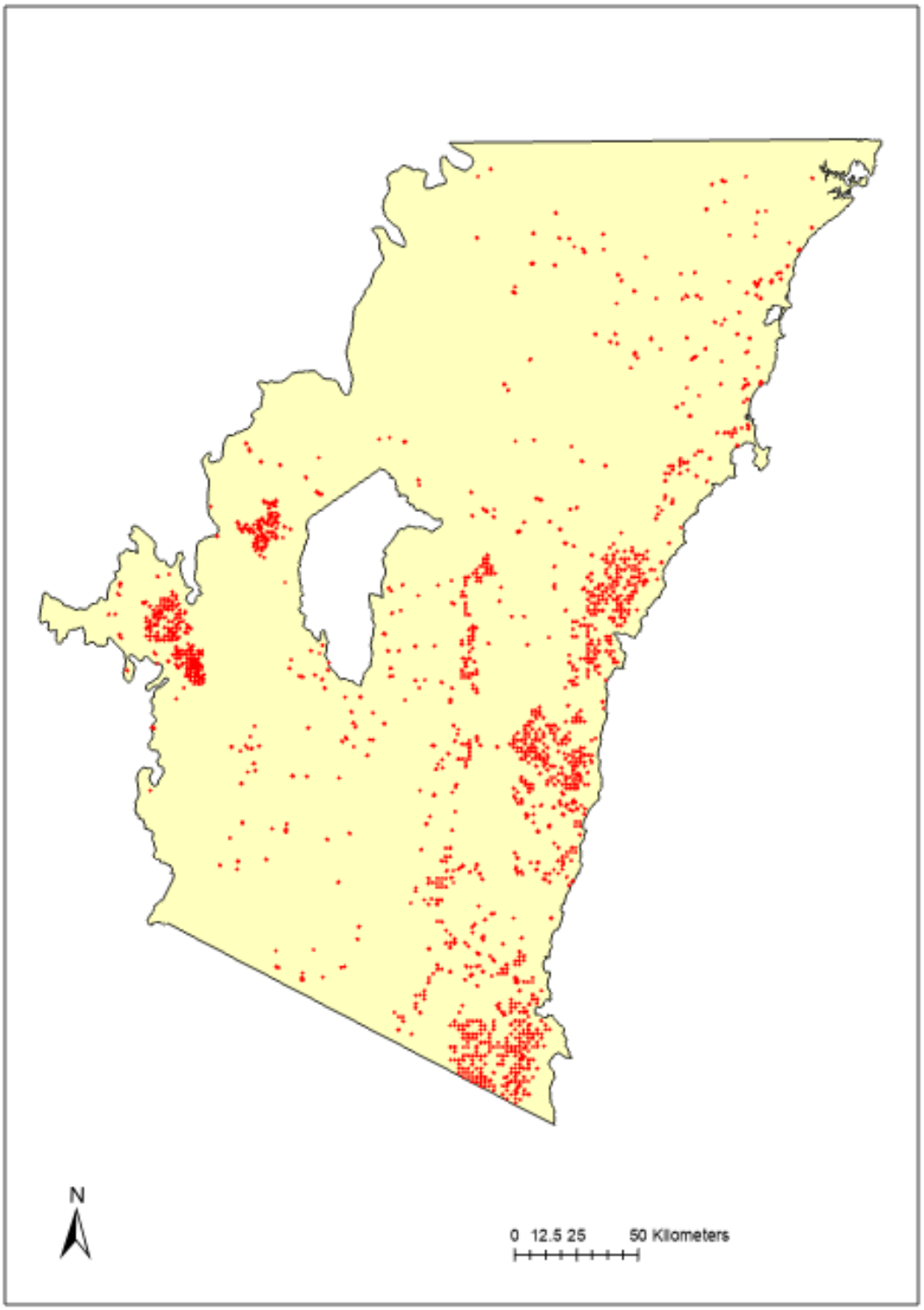


Figure 6: Location of 1523 reference plots for South Coast of NSW

Model Validation & Accuracy Assessment

The model showed a good agreement with the reference data, an overall accuracy of 80%, 95% confidence interval of 78.0% - 82.0%. The kappa value calculated is 0.77. Landis and Koch (1977) have proposed the following as standards for strength of agreement for the kappa coefficient: 0=poor, .01–.20=slight, .21–.40=fair, .41–.60=moderate, .61–.80=substantial, and .81–1=almost perfect. So, the agreement between the predicted values from the random forest and reference data is substantial.

The User's and producers accuracies are also calculated for each group. A two way table of the predicted values and the actual observed YAG classes is called a confusion matrix and is presented in Table 5. Table 6 presents the accuracies for the seven YAG classes.

Table 5: Confusion matrix for the KNN model fitted using 405 plots for South Coast of NSW.

	Reference YAG									
Predicted YAG	Alpine Ash	Brown Barrel - Messmate	Coastal Dry	Moist Coastal	Negligible Productive Types	Rainforest	Silvertop Ash	Spotted Gum	Tableland Gum - Peppermint	Yellow Stringybark - Gum
Alpine Ash	109								7	
Brown Barrel - Messmate		148	1		1		1		1	
Coastal Dry		1	155	2	21		4	7	6	14
Moist Coastal				34						
Negligible Productive Types					159				10	
Rainforest			1			36				
Silvertop Ash		1	24				193	2	2	6
Spotted Gum			30	9			2	133		1
Tableland Gum - Peppermint	10	1			101				148	
Yellow Stringybark - Gum		6	13	11				4	11	97

Table 6: Accuracy assessment of the KNN model for South Coast of NSW

YAGs	User's Accuracy	Producer's Accuracy
Alpine Ash	94.0%	91.6%
Brown Barrel - Messmate	97.4%	94.3%
Coastal Dry	73.8%	69.2%
Moist Coastal	100.0%	60.7%
Negligible Productive Types	94.1%	56.4%
Rainforest	97.3%	100.0%
Silvertop Ash	84.6%	96.5%
Spotted Gum	76.0%	91.1%
Tableland Gum - Peppermint	56.9%	80.0%
Yellow Stringybark - Gum	68.3%	82.2%

Yield Association Group Map of Private Native Forest, South Coast of NSW

A total of forty LiDAR, climatic, soil type, sentinel and topographic variables were used as predictor variables to produce a map of YAG groups. The resulting map is presented in figure 7. Figure 8 is

the plot of the forest area in hectares for each of the YAGs in private native forest, South Coast of NSW.

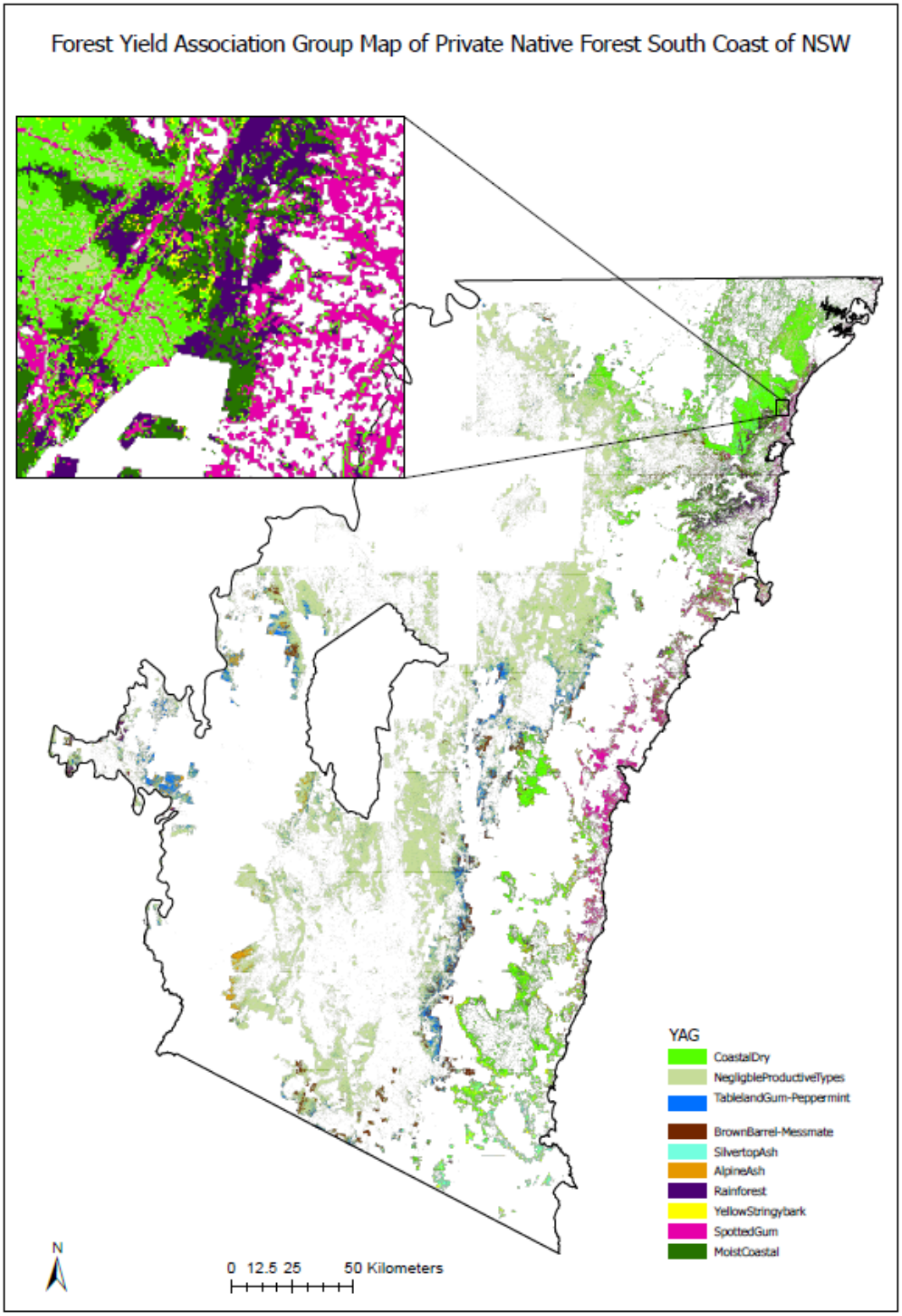


Figure 7: The map of the Yield Association Groups for the Private Native Forest of South Coast of NSW.

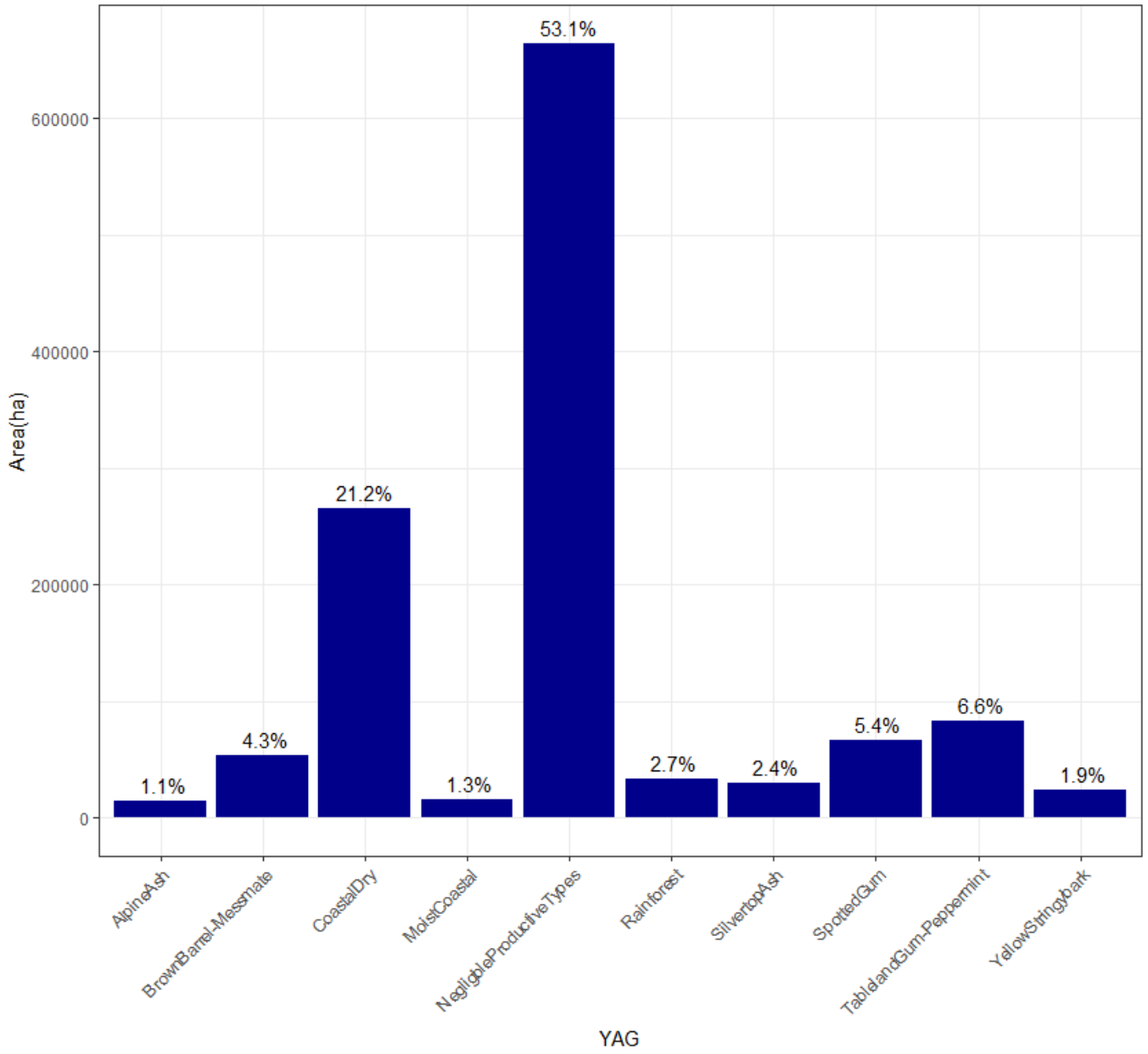


Figure 8: Area under the yield association groups in private native forest in South Coast of NSW. The percentages on the bar plots are area in percentage for each YAG group.

Limitations of the Study

For North Coast the major limitation of the study is the limited number of plots available as reference data. There were 405 reference plots with only 12 plots from Viney Scrub, 21 rainforest plots and 17 Swamp Sclerophyll. There was also clustering of the plots (Figure 6). Some parts of the North Coast area are completely not represented as LiDAR data is not available. Most of the reference data for the study has come from the FCNSW. More reference plots from other tenures should be included for future YAG mapping. The spatial services LiDAR layer does not cover the whole of the of PNF properties (Figure1). The white area is where there is no spatial services LiDAR. The LiDAR data used to produce the map is spatial services data, the point density for this data is much less than data collected in 2020 for NSW Local Land Services Private Native Forests (PNF)

research and development program with DPI Forest Science. The data was collected over a long period of time, mostly from year 2001 to 2015. Southern YAG calculations included the Sydney drinking water catchment and Commonwealth (Holsworthy Army Base) areas where forestry would be highly unlikely and therefore overestimated the area of Coastal Dry Forest potentially available for forestry.

Future Work

Field data collected on PNF areas could be used to further improve the YAG map, especially for YAG groups where the number of samples were low. The use of additional samples with better spatial spread would also further improve the maps.

Acknowledgments

This project was funded by Local Land Services and DPI. We thank Forestry Corporation of NSW for access to inventory data and Masoomeh Alaibakhsh for GIS support.

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Appendix A

North Coast YAG classification

North Coast YAGs are principally defined by the species mix of their canopy, their height and their geographic distribution.

Of the seven main YAGs, three can be distinguished by the species mix in their canopy, namely, **Rainforest, Blackbutt and Spotted Gum**.

To be classified as **Rainforest** the canopy of the YAG must be dominated by species which are fire sensitive viz. rainforest species. Note, Brush Box (*Lophostemon confertus),* Turpentine (*Syncarpia glomulifera*), Flooded Gum (*Eucalyptus grandis*) and Blue Gum (*Eucalyptus saligna*) can be found in and on the edge of rainforest but are not classified as rainforest species. This is because these species will not self-perpetuate within a rainforest via localised disturbance events (e.g. tree fall) as is typical of rainforest species, and instead take advantage of infrequent rainforest fire events to germinate.

Blackbutt and **Spotted Gum** are discrete 'forest types' but warrant their own YAG classification because of their preferred timber status and because they are very widespread. In the future there is scope to increase the number of 'forest types' that are classified and mapped as YAGs, such as Brush Box, Blue Gum and Flooded Gum, and Stringybarks because they are physically very distinct.

For a forest to qualify as a **Blackbutt** YAG, 50% of the canopy trees must be either Coastal Blackbutt (*Eucalyptus pilularis*) or Large-fruited Blackbutt (*Eucalytus pyrocarpa*). For a forest to qualify as a **Spotted Gum** YAG, Spotted Gum (*Corymbia maculata/henryi/variegata*) must be the dominant canopy species and constitute at least 33% of the canopy species mix.

Viney Scrub and **Swamp Sclerophyll Forest** can be distinguished on the basis of their canopy and understorey species mix.

Where canopy trees are fragmented and in a degraded state (poor health and condition), the forest may qualify as a **Viney Scrub** YAG. Viney Scrub YAG occurs predominantly at the moist end of the climatic spectrum where tree regeneration (following disturbance events) is not always successful due to factors including availability of eucalypt seed and dense understorey/vine growth inhibiting seed germination. For all other YAGs the canopy species mix is important but not a defining attribute.

Swamp sclerophyll forest can be identified by its canopy if dominated by swamp oak, paperbark, or mangrove species. However, Swamp sclerophyll forest can also have a canopy dominated by eucalypt species. In this case the YAG is identified by the presence of a ground stratum of moisture-loving plants including an abundance of sedges, rushes and ferns. Swamp sclerophyll forests are found on coastal flats, floodplains, drainage lines, lake margins, wetlands and estuarine fringes where soils are at least occasionally saturated, water-logged or inundated.

YAGs that do not fall into any of the categories described above can be divided into two broad groups based on their geographical distribution, those that grow at lower elevations, along the coast and sloping ranges (**Coastal Eucalypts**), and those that grow at higher elevations, on range tops and on the tablelands (**Tableland Eucalypts**). **Coastal Eucalypts** transition to **Tableland Eucalypts** between 650 metres and 950 metres above mean sea level. The elevation at which this transition occurs is affected by latitude and topographic features.

Coastal Eucalypts have a high proportion of dense durable species (e.g. Blackbutt, Spotted Gum, Tallowwood, Grey Gum and Ironbark) while **Tableland Eucalypts** are dominated by species of lower (oven dry) density and durability (e.g. Mountain Gum, Manna Gum, Peppermint, Mountain Grey Gum, Brown Barrel, Messmate and Silvertop Stringybark). Sydney Blue Gum is a dense, moderately durable species that is found in both coastal and tableland YAGs, commonly occupying the transition zone.

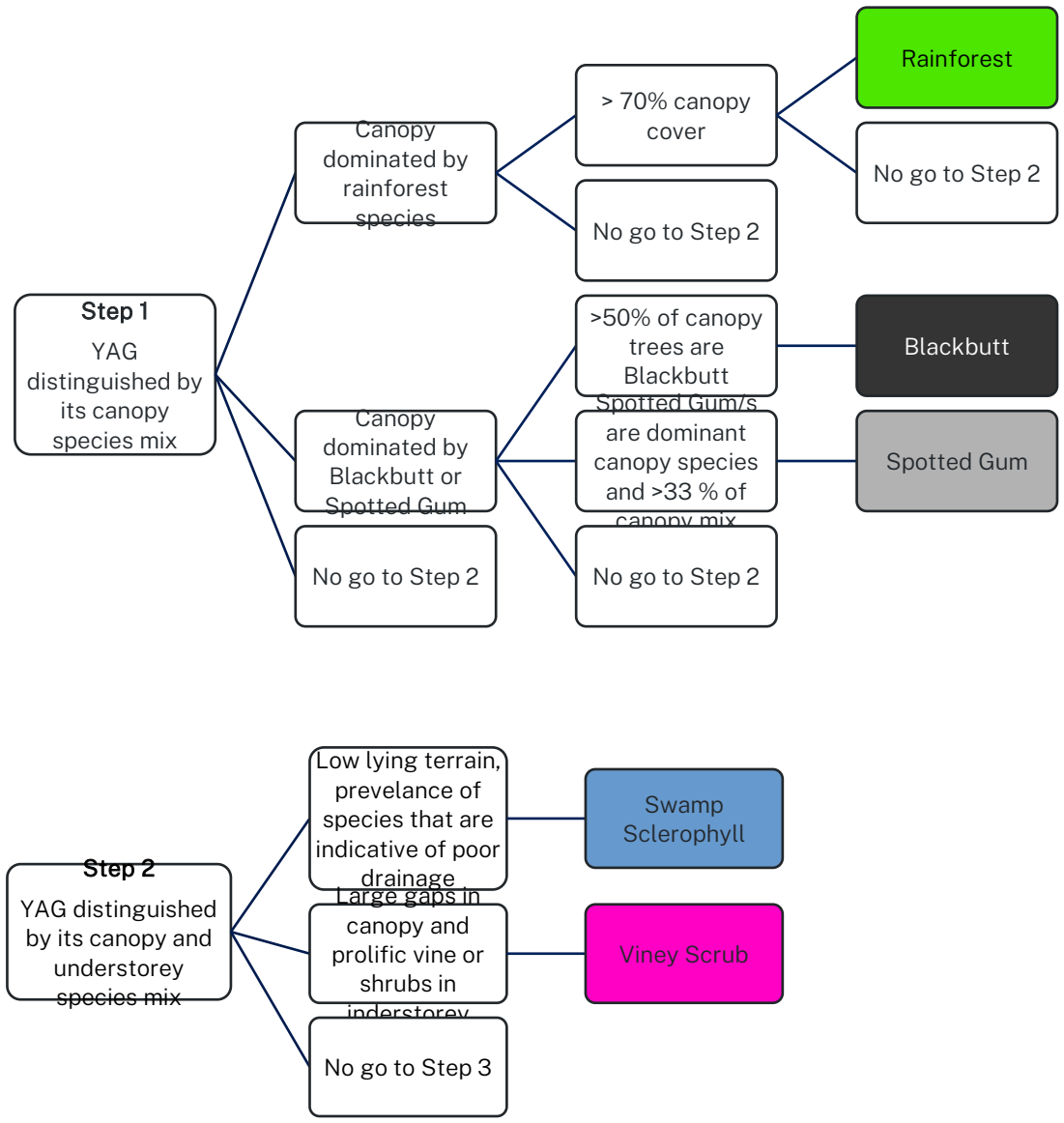
YAGs are also grouped by their inherent moisture level or wetness (e.g. dry, semi-moist, moist, rainforest and swamp). Moisture by itself, however, is not a reliable indicator of forest productivity or capacity to yield timber. For example, a swamp sclerophyll forest is lower yielding than a moist eucalypt forest.

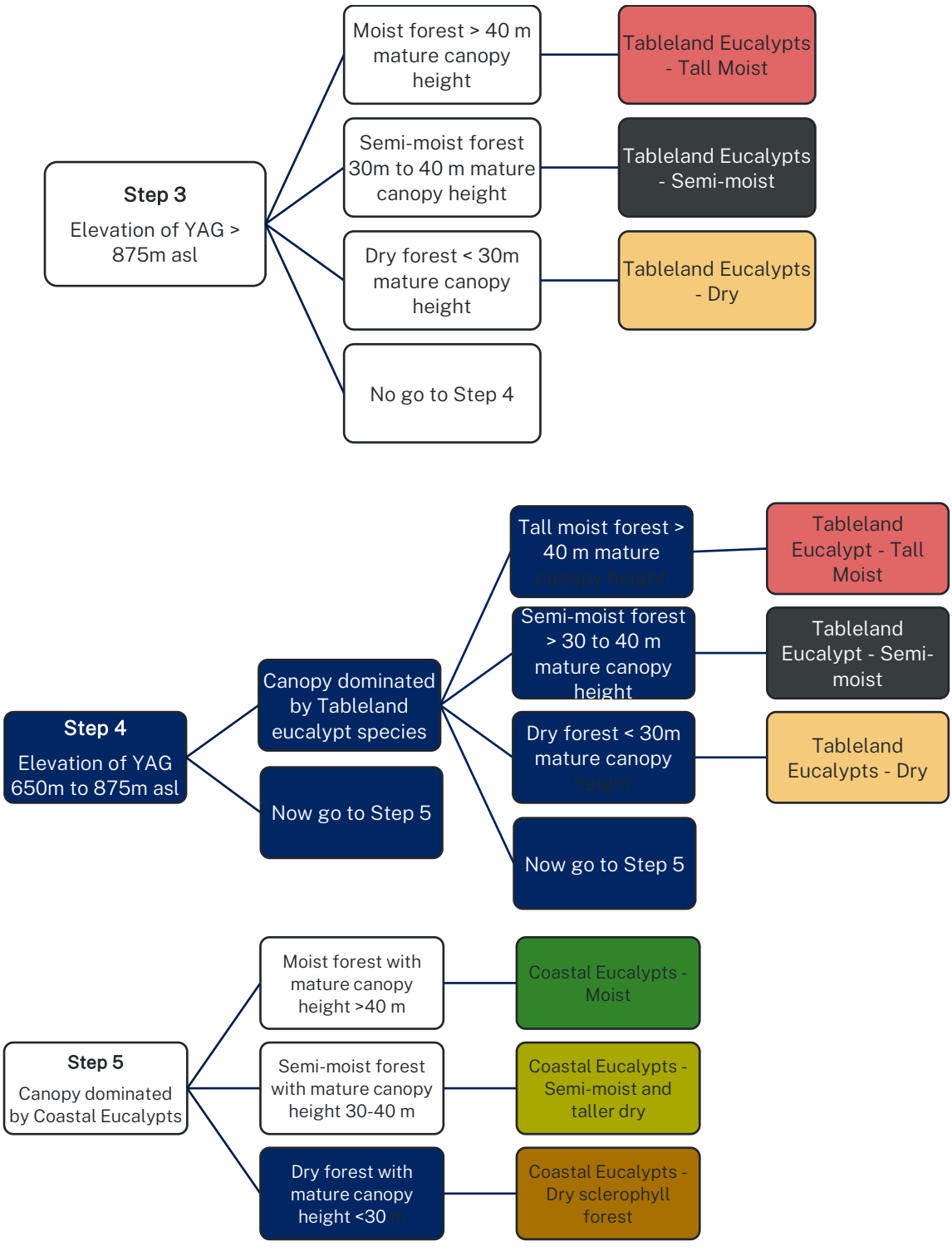
Mature tree canopy height is an important structural attribute that provides a reliable indicator of a forest's site productivity and its capacity to yield timber. Mature tree canopy heights[1] can range from as low as 5 metres on infertile dry sites to in excess of 60 metres on moist fertile sites. **Tall Moist Forests** (40m+) have the highest timber yielding potential, followed by **Semi-moist and Taller Dry Forests** (30-40m), while shorter **Dry Forests** (< 30m) have the least. Mature tree canopy height is not, however, a reliable indicator for Rainforest or Swamp sclerophyll YAGs.

North Coast native forests can be grouped into YAGs using the simple classification key shown at below. For more detailed YAG descriptions refer to the section title Yield Association Group Definitions.

[1] Note, there is a definitional difference between 'mature tree canopy height' and 'Site Index height'. Mature tree canopy height is equivalent to a P99 LiDAR canopy height while Site index height which was used in the YAG model is based on a P90 LiDAR canopy height. To directly compare 'mature tree canopy height' to 'Site Index height' subtract 5 metres (i.e. a forest with a 'mature tree canopy height' of 40 metres will have a 'Site Index height' of 35 metres).

North Coast YAG KEY





YAG Classification Key (simplified)

North Coast Yield Association Group Definitions

1. Rainforest

Description

- ✓ Luxuriant appearance, canopy dominated by rainforest species. Canopy may also contain occasional emergent sclerophyll species (e.g. Brush Box, Turpentine, Flooded Gum or Sydney Blue Gum), provided they are not dominant.
- ✓ Occurs where fires are absent or infrequent, across a range of landforms including volcanic plateaus, sheltered hillsides, coastal dunes, floodplains and riparian zones.
- ✓ Usually has a closed canopy with projected foliage cover greater than 70%.
- ✓ Gullies and south and east aspects are favoured sites. Broader distribution occurs where soils have high fertility.
- ✓ Cool and shady microclimate exists beneath canopy, one to three vertical layers, vines and epiphytes present.
- ✓ Height sub-formations (5-10m, 10-30m and 30m+).
- ✓ Structural sub-formations:
    - i. Subtropical (notophyll vine forest) – 10-60 canopy species, 1300 mm rain.
    - ii. Warm temperate (simple notophyll evergreen vine forest) – 3-15 canopy species, 1300 mm rain, emergent *Araucaria,* or remnant *Eucalyptus* or *Lophostemon*.

iii. Cool temperate (microphyll fern forest) – 1-3 canopy species , 1750 – 3500 mm, usually above 900m elevation, e.g. *Nothofagus moorei*
iv. Dry (araucarian notophyll vine forest) – 10- 30 canopy species, 600-1100 mm rain.

Canopy Indicator Species (note not all species occur in each of the sub-formations)

Common Name	*Scientific Name*
Antarctic Beech	*Nothofagus moorei*
Black Bean	*Castanospermum australe*
Black Booyong	*Argyrodendron actinophyllum*
Brush Box	*Lophostemon confertus*
Camphor Laurel (invasive exotic)	*Cinnamomum camphora*
Camphorwood	*Cinnamomum oliveri*
Coachwood	*Ceratopetalum apetalum*
Corkwood	*Endiandra sieberi*
Giant Stinger	*Dendrocnide excelsa*
Hoop Pine	*Araucaria cunninghamii*
Lilly Pilly	*Syzygium smithii*
Figs	*Ficus spp.*
Quandongs	*Elaeocarpus spp.*
Red Cedar	*Toona ciliata*
Silky Oak	*Grevillea robusta*
Tuckeroo	*Cupaniopsis anacardioides*
Turpentine	*Syncarpia glomulifera*
White Beech	*Gmelina leichhardtii*
White Booyong	*Argyrodendron trifoliolatum*
White Cedar	*Melia azedarach*
Yellow Carabeen	*Sloanea woollsii*

2. Viney Scrub

Description

- ✓ A highly fragmented canopy comprising remnant, dead or dying forest trees. Remnant trees either large and old or younger with poor canopy health.
- ✓ Predominance of vines and shrubs that form dense thickets (usually 2m to 8m in height). Introduced shrub and vine species common or dominant (e.g. Lantana).
- ✓ Vines commonly extending up trunks of remnant and dead trees.
- ✓ Merchantable trees rare or absent.
- ✓ Often a former Rainforest or Coastal Eucalypt forest that has failed to regenerate or is in an early succession stage.
- ✓ May have been previously cleared for agriculture.

Indicator Species

Common Name	*Scientific Name*
Lantana	*Lantana camara*
Native Cockspur	*Maclura cochinchinensis*
Water Vine/Kangaroo Vine	*Cissus spp.*
Burny Vine	*Trophis scandens*
Stinger	*Dendrocnide* spp.
Rainforest species	Refer section 1
Mixed Coastal Eucalypts	Refer sections 5,6 and 7

3. Blackbutt

Description

- ✓ Blackbutt makes up over 50 per cent and not infrequently up to 100 per cent of the stand (canopy and stocking).
- ✓ Common throughout the coastal districts of the study area to 750m elevation (occasionally to around 900m).
- ✓ Tolerates a range of soil fertilities. Has a preference for well drained siliceous soils.
- ✓ Includes moist, semi-moist and dry types.
- ✓ More than 25 m in height, commonly around 30-35 metres.
- ✓ More than 900 mm rainfall.

Canopy Indicator Species (dominant species in bold)

Common Name	*Scientific Name*
Blackbutt	***Eucalyptus pilularis***
Large-fruited Blackbutt	***Eucalyptus pyrocarpa***
Bangalay	*Eucalyptus botryoides*
Broad-leaved White Mahogany	*Eucalyptus umbra*
Brush Box	*Lophostemon confertus*
Narrow-leaved White Mahogany	*Eucalyptus acmenoides*
Native Fig	*Ficus spp*
Pink Bloodwood	*Corymbia intermedia*
Red Bloodwood	*Corymbia gummifera*
Red Mahogany	*Eucalyptus resinifera*
Spotted Gum	*Corymbia maculata*
Steel Box	*Eucalyptus rummeryi*
Swamp Mahogany	*Eucalyptus robusta*
Sydney Blue Gum	*Eucalyptus saligna*
Tallowwood	*Eucalyptus microcorys*
Turpentine	*Syncarpia glomulifera*

4. Spotted Gum

Description

- ✓ Spotted Gum is the dominant species and constitutes more than one third of the canopy.
- ✓ Common throughout the coastal districts of the study area.
- ✓ Commonly occurs on gravelly soils with heavier texture than those preferred by Blackbutt. Often associated with or growing near Blackbutt stands.
- ✓ Can occur in association with a large number of other eucalypt species.
- ✓ Not distinguished by its understory or moisture status though semi-moist are the most common.
- ✓ More than 20 m in height, commonly around 30 metres.
- ✓ Common on lower elevation gently sloping terrain throughout the coastal districts. May also occur on more rugged steeper terrain.

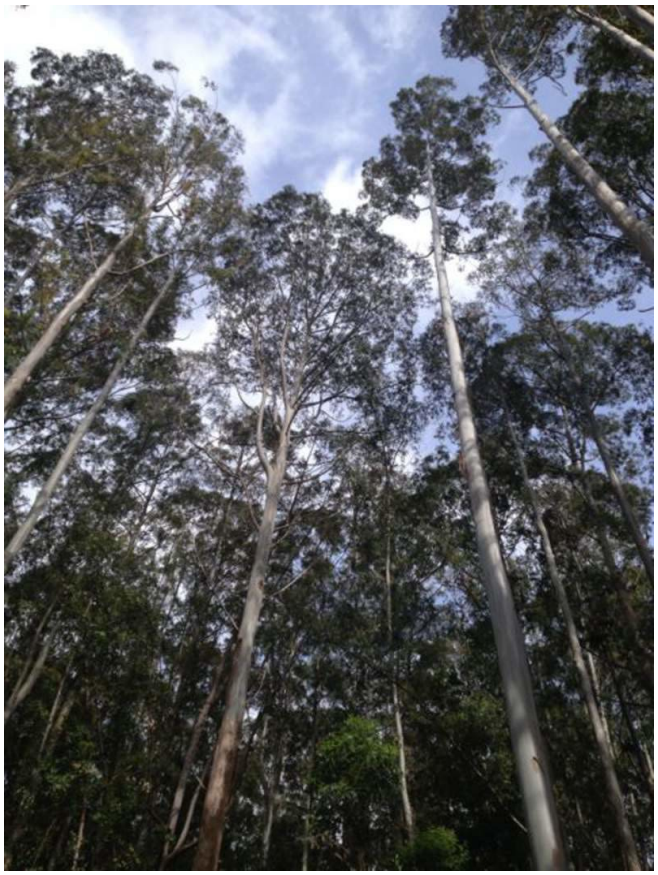
Canopy Indicator Species (dominant species bolded)

Common Name	*Scientific Name*

Spotted Gum	*Corymbia variegata*
Southern Spotted Gum	*Corymbia maculata*
Large-leaved Spotted Gum	*Corymbia henryi*
Bangalay	*Eucalyptus botryoides*
Blackbutt	*Eucalyptus pilularis*
Blue-leaved Stringybark	*Eucalyptus agglomerata*
Broad-leaved Ironbark	*Eucalyptus fibrosa*
Broad-leaved Red Ironbark	*Eucalyptus fibrosa*
Broad-leaved White Mahogany	*Eucalyptus umbra*
Cabbage Gum	*Eucalyptus amplifolia*
Diehard Stringybark	*Eucalyptus cameronii*
Dungog Grey Gum	*Eucalyptus canaliculata*
Dunn's White Gum	*Eucalyptus dunnii*
Forest Red Gum	*Eucalyptus tereticornis*
Grey Box	*Eucalyptus moluccana*
Grey Gum	*Eucalyptus biturbinata*
Grey Gum	*Eucalyptus punctate /canaliculata*
Grey Ironbark	*Eucalytus siderophloia*
Grey Ironbark	*Eucalyptus paniculata*
Large-fruited Blackbutt	*Eucalyptus pyrocarpa*
Large-fruited Blackbutt	*Eucalyptus pyrocarpa*
Narrow-leaved Ironbark	*Eucalyptus crebra*
Narrow-leaved White Mahogany	*Eucalyptus acmenoides*
Pink Bloodwood	*Corymbia intermedia*
Red Bloodwood	*Corymbia gummifera*
Small-fruited Grey Gum	*Eucalyptus propinqua*
Steel Box	*Eucalyptus rummeryi*
Swamp Mahogany	*Eucalyptus robusta*
Swamp Oak	*Casuarina glauca*
Sydney Blue Gum	*Eucalyptus saligna*
Tallowwood	*Eucalyptus microcorys*
Turpentine	*Syncarpia glomulifera*
White-topped Box	*Eucalyptus quadrangulata*

White Stringybark	*Eucalyptus globoidea/eugenioides*
Woollybutt	*Eucalytpus longifolia*

5. Coastal Eucalypts – Tall Moist



Description

- ✓ Tall moist sclerophyll forest attaining over 40 metres in height containing one or more eucalypt species that is not dominated by Spotted Gum or Blackbutt.
- ✓ Includes pure stands of Brush Box, Flooded Gum and Sydney Blue Gum.
- ✓ Mixed species stands typically include Sydney Blue Gum, Tallowwood and Turpentine
- ✓ Occupies moist sheltered sites with deep fertile soils in areas of high annual rainfall.
- ✓ Carries a dense and lush understory of mesophytic shrubs and herbs which may be converted to dense ferns by burning.
- ✓ Unlike rainforest can dry out and become fire prone during drought.

Canopy Indicator Species (most common indicator species bolded)

Common Name	*Scientific Name*
Flooded Gum	*Eucalyptus grandis*
Sydney Blue Gum	*Eucalyptus saligna*
Tallowwood	*Eucalyptus microcorys*
Turpentine	*Syncarpia glomulifera*
Bangalay	*Eucalyptus botryoides*

Blackbutt	*Eucalyptus pilularis*
Broad-leaved Paperbark	*Melaleuca quinquenervia*
Broad-leaved White Mahogany	*Eucalyptus umbra*
Brush Box	*Lophostemon confertus*
Camphor Laurel (invasive exotic)	*Cinnamomum camphora*
Dunn's White Gum	*Eucalyptus dunnii*
Grey Ironbark	*Eucalytus siderophloia*
Grey Ironbark	*Eucalyptus paniculata*
Hoop Pine	*Araucaria cunninghamii*
Narrow-leaved White Mahogany	*Eucalyptus acmenoides*
Native Fig	*Ficus spp*
Pink Bloodwood	*Corymbia intermedia*
Red Bloodwood	*Corymbia gummifera*
Red Mahogany	*Eucalyptus resinifera*
Roundleaved Gum	*Eucalyptus deanei*
Small-fruited Grey Gum	*Eucalyptus propinqua*
Spotted Gum	*Corymbia maculata, Corymbia variegata*
Swamp Mahogany	*Eucalyptus robusta*
Swamp Oak	*Casuarina glauca*

6. Coastal Eucalypts - Semi-moist & Taller Dry Types

Description

- ✓ Semi-moist sclerophyll forest.
- ✓ Grows between sheltered and exposed sites on moderate to high fertility soils.
- ✓ Mature trees range between 30 m and 40 m in height.
- ✓ Usually, a mix of eucalypt species that is not dominated by Spotted Gum or Blackbutt.

✓ Commonly features tall well-formed examples from the durable species mix group (e.g. Grey Box, Grey Gum, Grey Ironbark, Steel Box, Turpentine, Spotted Gum, Blackbutt and Forest Red Gum).

Canopy Indicator Species (most common indicator species bolded)

Common Name	*Scientific Name*
Bangalay	*Eucalyptus botryoides*
Blackbutt	***Eucalyptus pilularis***
Blue-leaved Stringybark	***Eucalyptus agglomerata***
Grey Ironbark	***Eucalytus siderophloia***
Narrow-leaved White Mahogany	***Eucalyptus acmenoides***
River Oak	*Casuarina cunninghamiana*
Small-fruited Grey Gum	***Eucalyptus propinqua***
Spotted Gum	***Corymbia maculata, Corymbia variegata***
Steel Box	***Eucalyptus rummeryi***
Sydney Blue Gum	***Eucalyptus saligna***
Turpentine	***Syncarpia glomulifera***
White-topped Box	***Eucalyptus quadrangulata***
Broad-leaved Ironbark	*Eucalyptus fibrosa*
Broad-leaved Red Ironbark	*Eucalyptus fibrosa*
Broad-leaved White Mahogany	*Eucalyptus umbra*
Cabbage Gum	*Eucalyptus amplifolia*
Diehard Stringybark	*Eucalyptus cameronii*
Dungog Grey Gum	*Eucalyptus canaliculata*
Dunn's White Gum	*Eucalyptus dunnii*
Forest Red Gum	*Eucalyptus tereticornis*
Grey Box	*Eucalyptus moluccana*
Grey Gum	*Eucalyptus biturbinata*
Grey Gum	*Eucalyptus punctata*
Grey Ironbark	*Eucalytus siderophloia*
Grey Ironbark	*Eucalyptus paniculata*
Hoop Pine	*Araucaria cunninghamii*
Large-fruited Blackbutt	*Eucalyptus pyrocarpa*
Narrow-leaved Ironbark	*Eucalyptus crebra*
Native Fig	*Ficus spp*
Pink Bloodwood	*Corymbia intermedia*
Red Bloodwood	*Corymbia gummifera*
River Oak	*Casuarina cunninghamiana*
Swamp Mahogany	*Eucalyptus robusta*
Swamp Oak	*Casuarina glauca*
Tallowwood	*Eucalyptus microcorys*
Woollybutt	*Eucalytpus longifolia*

7. Coastal Eucalypts - Dry

Description

- ✓ Dry Sclerophyll forest
  - ✓ Mixed species forest not dominated by Spotted Gum or Blackbutt.
- ✓ Mature trees predominantly less than 30 m in height.
- ✓ Has a xeric and open grassy understorey which is maintained through burning.
- ✓ Exposed, dry and or infertile sites.
- ✓ Fire plays a vital role in regeneration.

Canopy Indicator Species (most common indicator species bolded)

Common Name	*Scientific Name*
Broad-leaved White Mahogany	***Eucalyptus umbra***
Forest Red Gum	***Eucalyptus tereticornis***
Grey Gum	***Eucalyptus biturbinata***
Grey Gum	***Eucalyptus punctata***
Red Bloodwood	***Corymbia gummifera***
Scribbly Gum	***Eucalyptus racemosa***
Smooth-barked Apple	***Angophora costata***
White Stringybark	***Eucalyptus globoidea***
Thin-leaved Stringybark	***Eucalyptus eugenioides***
Blackbutt	*Eucalyptus pilularis*
Black Cypress Pine	*Callitris endlicheri*
Blakely's Red Gum	*Eucalyptus blakelyi*
Broad-leaved Ironbark	*Eucalyptus fibrosa*
Broad-leaved Red Ironbark	*Eucalyptus fibrosa*
Broad-leaved Stringybark	*Eucalyptus caliginosa*
Cabbage Gum	*Eucalyptus amplifolia*
Diehard Stringybark	*Eucalyptus cameronii*
Dungog Grey Gum	*Eucalyptus canaliculata*
Forest Oak	*Allocasuarina torulosa*
Grey Box	*Eucalyptus moluccana*
Grey Gum	*Eucalyptus biturbinata*
Grey Gum	*Eucalyptus punctata*
Grey Ironbark	*Eucalytus siderophloia*
Grey Ironbark	*Eucalytus paniculata*
Kurrajong	*Brachychiton populneus*
Large-fruited Blackbutt	*Eucalyptus pyrocarpa*
Mugga Ironbark	*Eucalyptus sideroxylon*
Narrow-leaved Ironbark	*Eucalyptus crebra*
Red Bloodwood	*Corymbia gummifera*
River Oak	*Casuarina cunninghamiana*
Rough-barked Apple	*Angophora floribunda*
Silvertop Ash	*Eucalyptus seiberi*
Smooth-barked Apple	*Angophora costata*
Scribbly Gum	*Eucalyptus signata*
Swamp Oak	*Casuarina glauca*
Tallowwood	*Eucalyptus microcorys*
White Box	*Eucalyptus albens*
White Cypress	*Callitris glaucophylla*
Woollybutt	*Eucalytpus longifolia*
Yellow Box	*Eucalyptus melliodora*

8. Swamp Sclerophyll

Description

- ✓ Includes eucalypt, paperbark, swamp oak and mangrove forests which grow on coastal flats, floodplains, drainage lines, lake margins, wetlands and estuarine fringes where soils are at least occasionally saturated, water-logged or inundated.
- ✓ A ground stratum of moisture-loving plants including an abundance of sedges, rushes and ferns.
- ✓ Generally, less than 30 metres in height.

Canopy Indicator Species (most common indicator species bolded)

Common Name	*Scientific Name*
Bangalay	***Eucalyptus botryoides***
Broad-leaved Paperbark	***Melaleuca quinquenervia***
Swamp Oak	**Casuarina glauca**
Swamp Mahogany	***Eucalyptus robusta***
Forest Red Gum	***Eucalyptus tereticornis***
Cabbage Palm	*Livistona australis*
Mangrove	*Hibiscus tiliaceus, Rhizophore mucronata, Bruguiera gymnorrhiza*
Narrow leaved Paperbark	*Melaleuca alternifolia, Melaleuca linariifolia*
Prickly Paperbark	*Melaleuca styphelioides*
Red Bloodwood	*Corymbia gummifera*
Red Mahogany	***Eucalyptus resinifera***

9. Tableland Eucalypts – Tall Moist

Description

- ✓ Moist sclerophyll forest over 40 m in height and generally above 750 m elevation.
- ✓ More than half of the forest canopy must be species unique to the Tablelands.
- ✓ Sheltered or semi-sheltered sites
- ✓ Deep and fertile soils,
- ✓ Reliable rainfall.
- ✓ Brown Barrel can be a dominant species as can better formed stands of New England Blackbutt, Silvertop Stringybark, Messmate, Maiden's Gum, Manna Gum and Narrow-leaved Peppermint.

Canopy Indicator Species (most common indicator species bolded)

Common Name	*Scientific Name*
Brown Barrel	***Eucalyptus fastigata***
New England Blackbutt	***Eucalyptus campanulata***
Messmate	***Eucalyptus obliqua***
Maiden's Gum (Monkey Gum)	*Eucalyptus cypellocarpa*
Manna Gum (Ribbon Gum)	*Eucalyptus viminalis*
Mountain Gum	*Eucalyptus dalrympleana*
Narrow-leaved Peppermint	*Eucalyptus radiata*
Silvertop Stringybark	*Eucalyptus laevopinea*
Sydney Blue Gum	*Eucalyptus saligna*
Tallowwood	*Eucalyptus microcorys*
White-topped Box	*Eucalyptus quadrangulata*

10.Tableland Eucalypts – Semi-Moist and Taller Dry

- ✓ Semi-moist sclerophyll forest generally occurring above 750 m elevation
- ✓ Mature trees attain between 30 m and 40 m in height.
- ✓ More than half of the forest canopy species must be unique to the Tablelands.
- ✓ Moderately fertile soils

Canopy Indicator Species (most common indicator species bolded)

Common Name	*Scientific Name*
Silvertop Stringybark	***Eucalyptus laevopinea***
Mountain Gum	***Eucalyptus dalrympleana***
Manna Gum (Ribbon Gum)	***Eucalyptus viminalis***
Blue Mountains Ash	*Eucalyptus oreades*
Brown Barrel	*Eucalyptus fastigata*
Maiden's Gum (Monkey Gum)	*Eucalyptus cypellocarpa*
Messmate	*Eucalyptus obliqua*
Narrow-leaved Peppermint	*Eucalyptus radiata*
New England Blackbutt	*Eucalyptus campanulata*
Sydney Blue Gum	*Eucalyptus saligna*
Tallowwood	*Eucalyptus microcorys*
White-topped Box	*Eucalyptus quadrangulata*

11. Tableland Eucalypts – Dry

Description

- ✓ Dry sclerophyll forest usually 30 m in height or less generally above 750m elevation.
- ✓ More than half of the forest canopy must be species unique to the Tablelands.
- ✓ Exposed sites, shallow and low-mod fertility soils.
- ✓ Includes forests dominated by Stringybark species.

Canopy Indicator Species

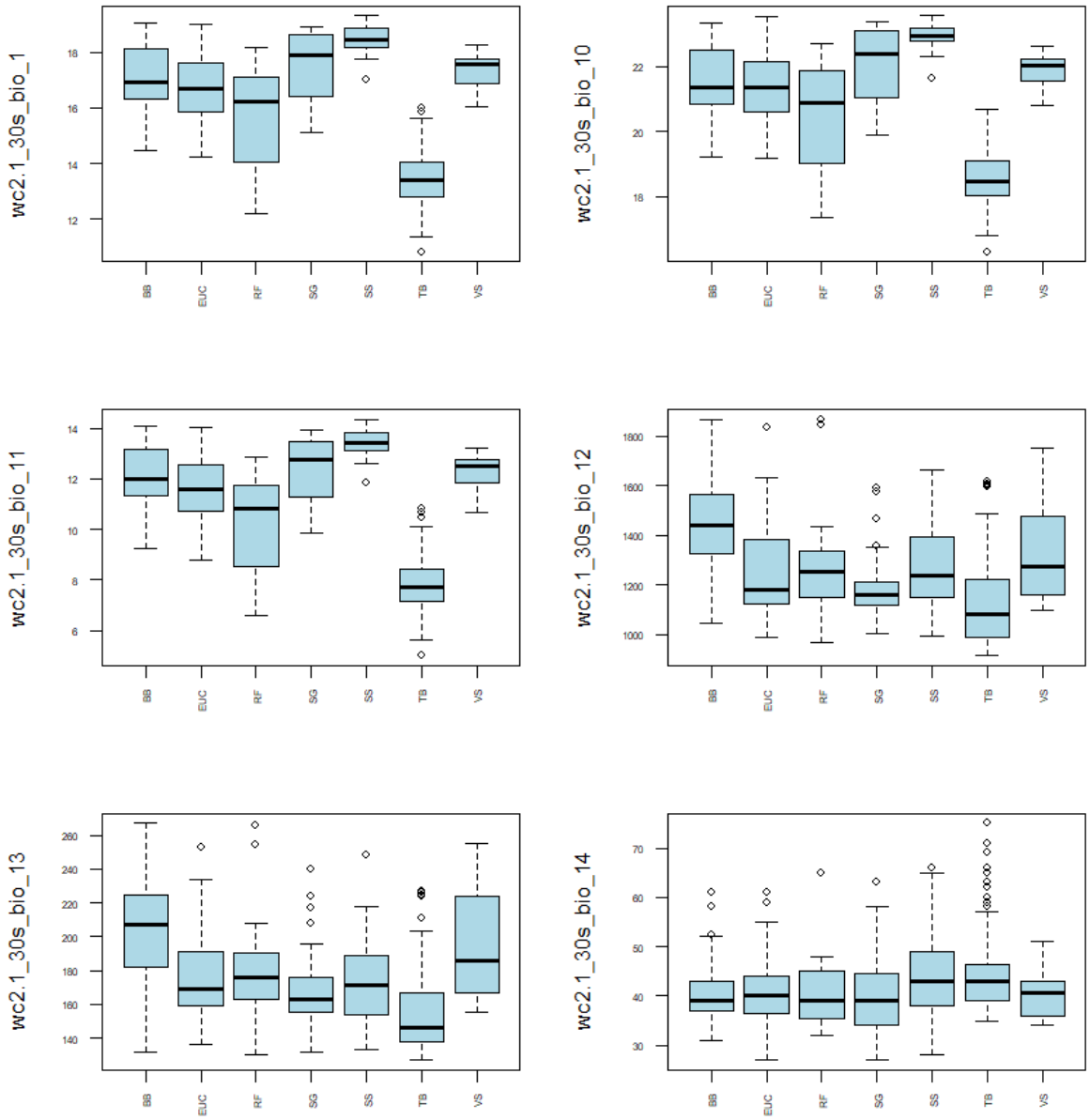
Common Name	*Scientific Name*
Blakely's Red Gum	***Eucalyptus blakelyi***
Broad-leaved Stringybark	***Eucalyptus caliginosa***
Narrowleaved Peppermint	***Eucalyptus radiata***
New England Blackbutt (Gum-topped Peppermint)	***Eucalyptus andrewsii***
New England Blackbutt	***Eucalyptus campanulata***
Black Cypress Pine	*Callitris endlicheri*
Cabbage Gum	*Eucalyptus amplifolia*
Caley's Ironbark	*Eucalyptus caleyi*
McKie's Stringybark	*Euclayptus mckieana*
Moonbi Apple	*Eucalyptus malacoxylon*
Rough-barked Apple	*Angophora floribunda*
Scribbly Gum	*Eucalyptus rossii*
Silvertop Ash	*Eucalyptus seiberi*
Silvertop Stringybark	*Eucalyptus laevopinea*
Snow Gum	*Eucalyptus pauciflora*
Tenterfield Woollybutt	*Eucalyptus banksii*
White Cypress	*Callitris glaucophylla*

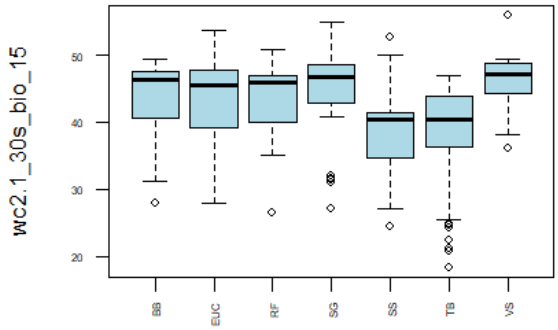
References

Forestry Commission of NSW (1965) Research Note No. 17 Forest Types in New South Wales. Available at https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0014/390011/Forest-Types-in-NSW.pdf

Appendix B

Box plot of the predictor variables with the YAG groups.

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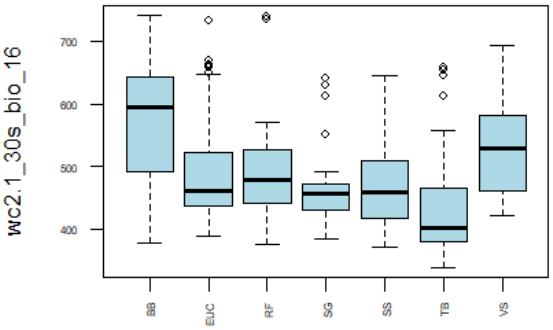
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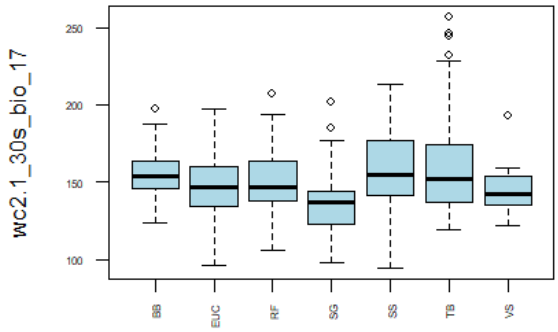
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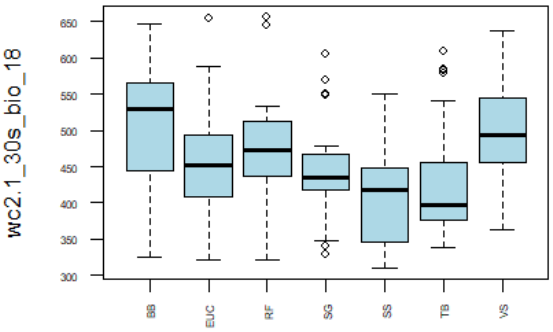
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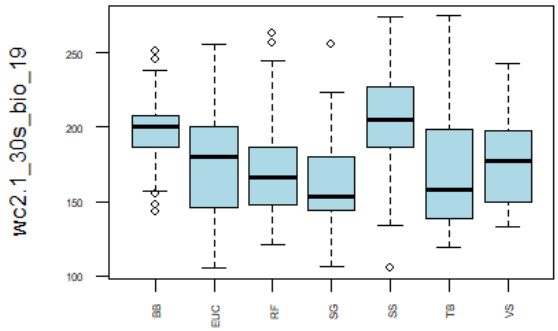
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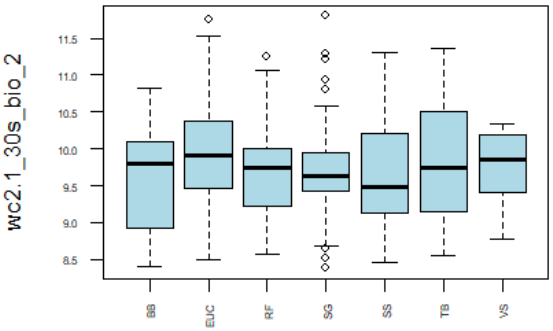
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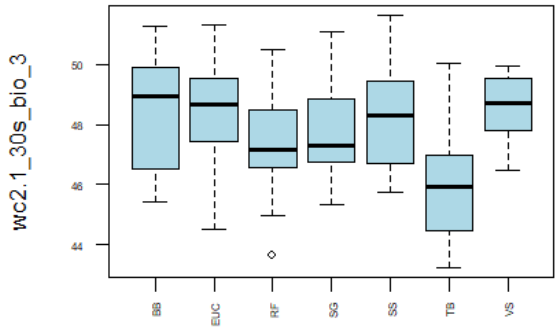
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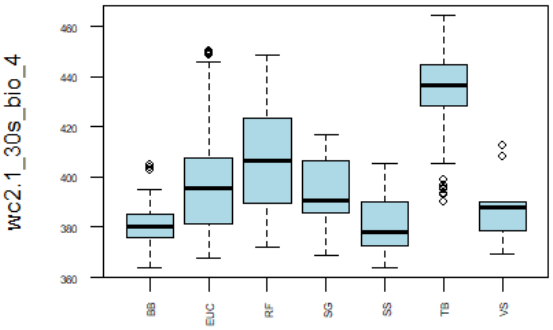
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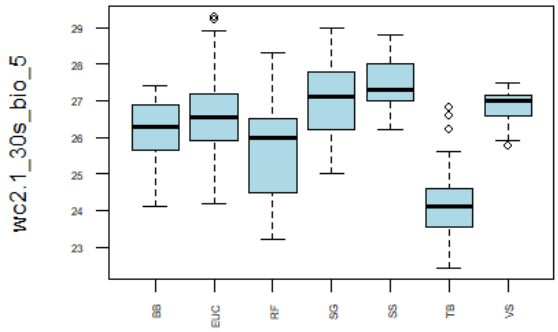
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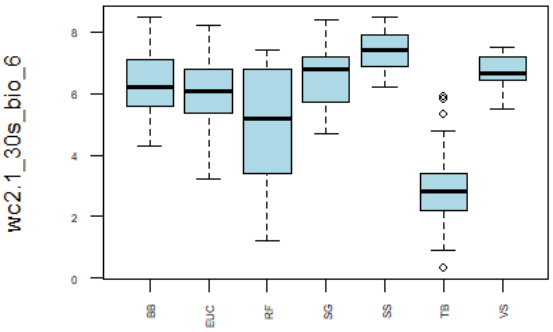
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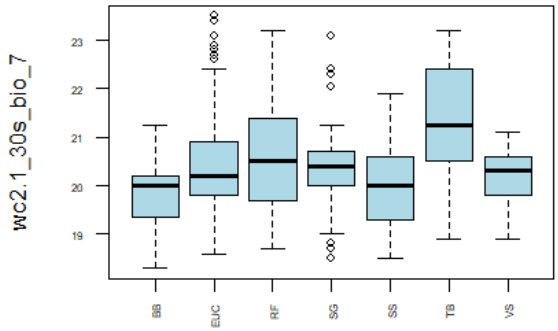
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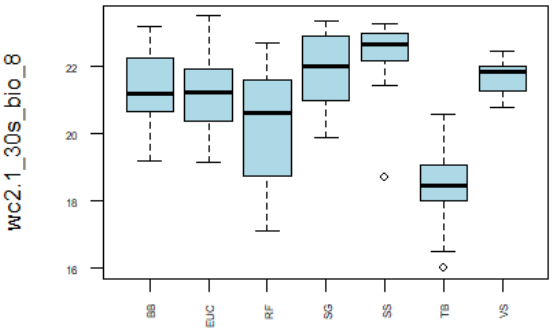
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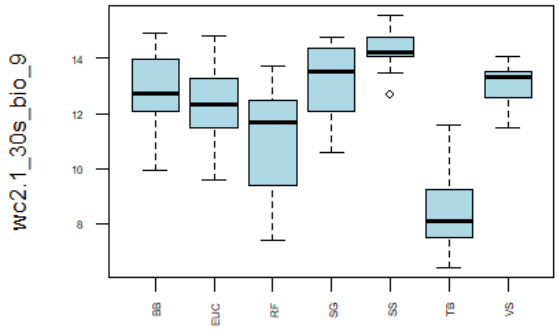
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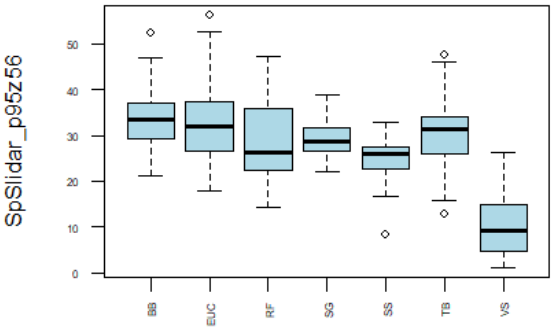
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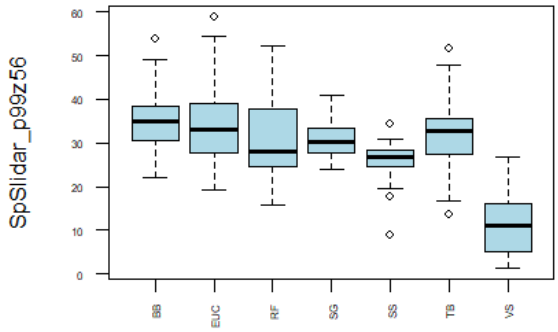
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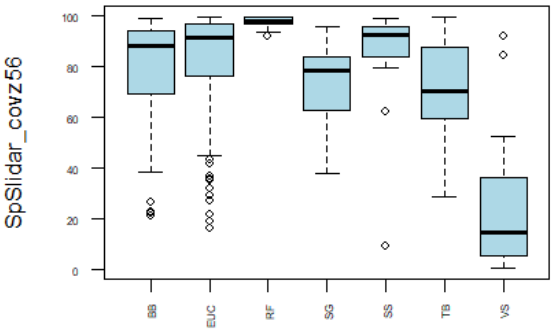
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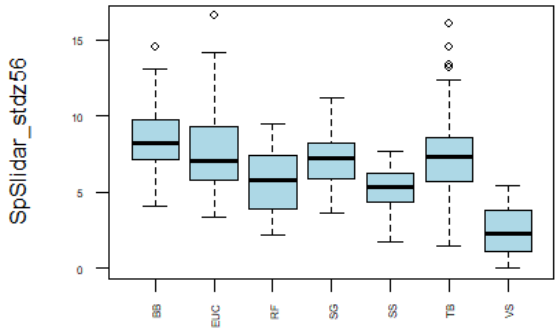
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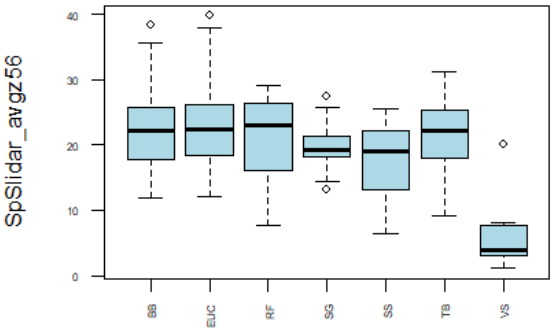
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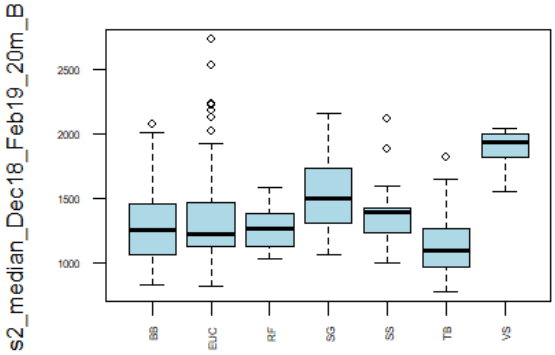
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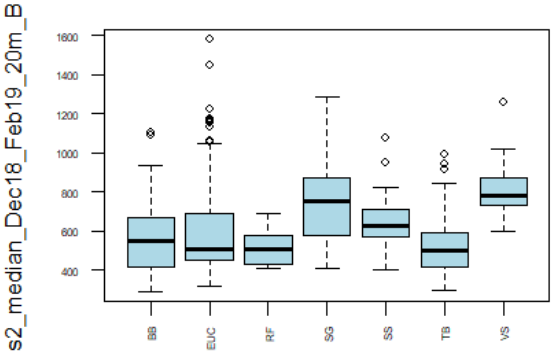
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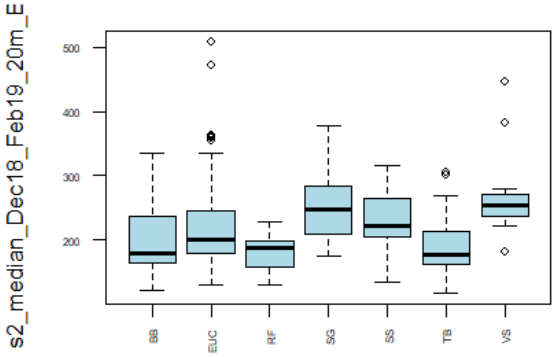
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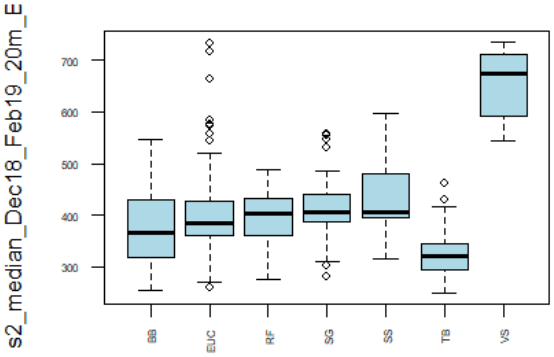
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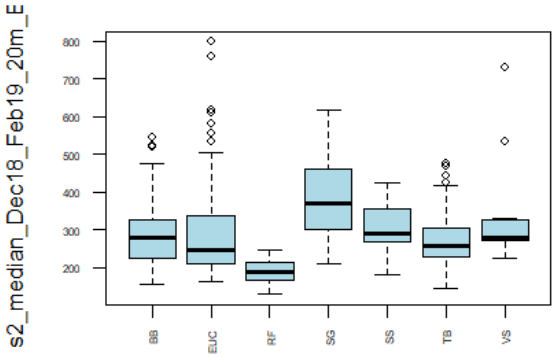
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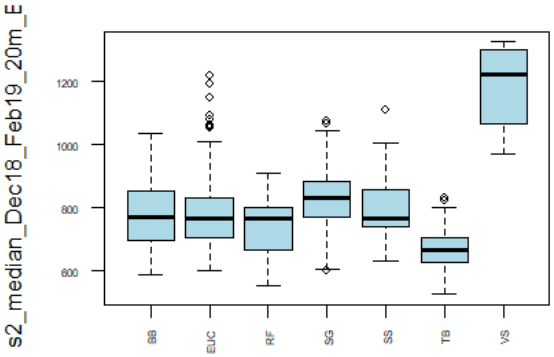
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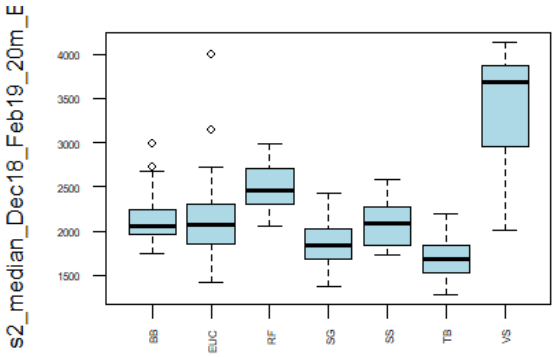
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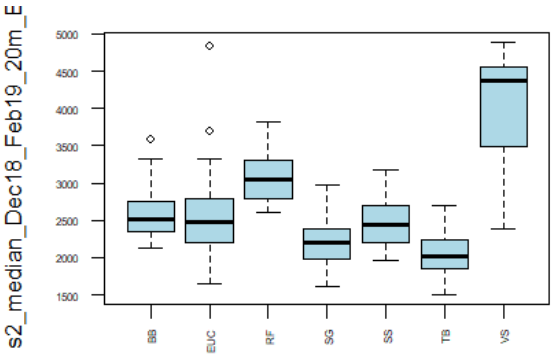
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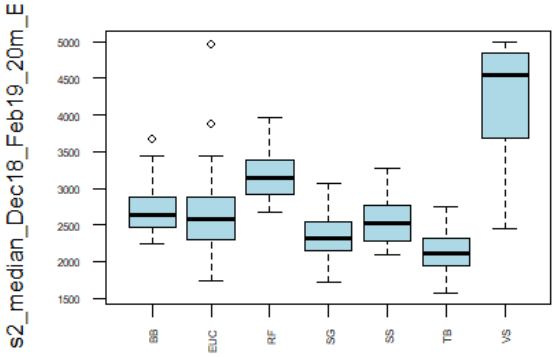
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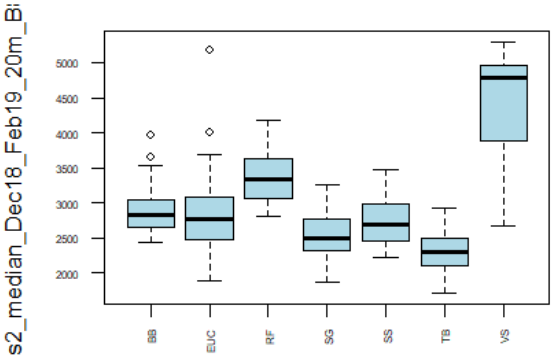
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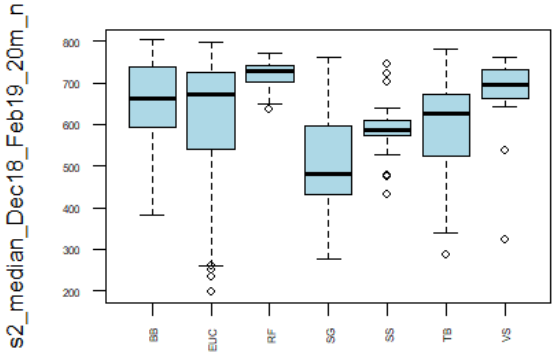
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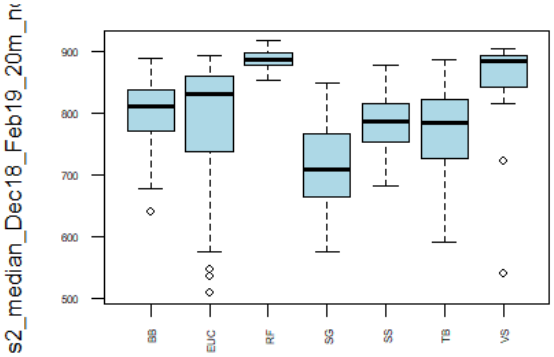
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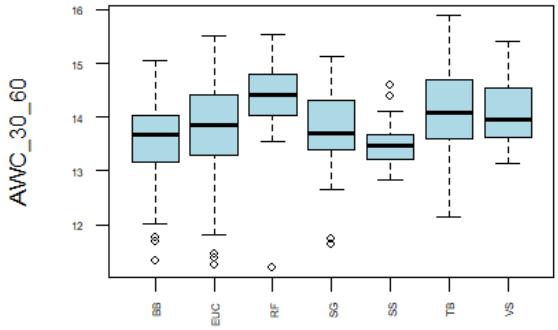
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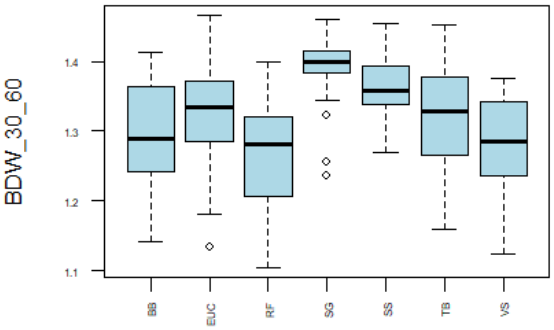
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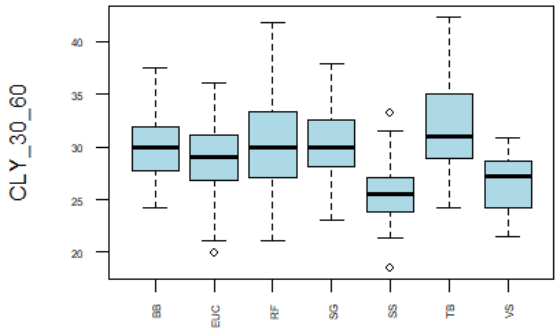
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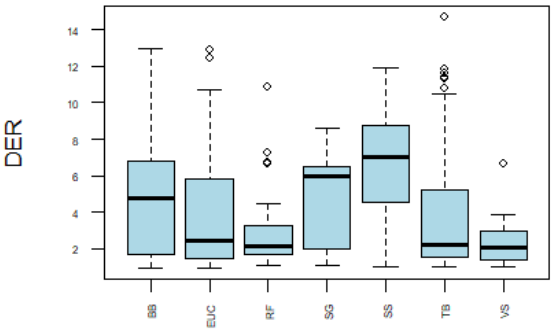
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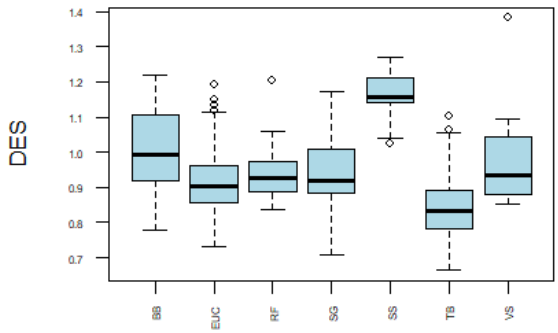
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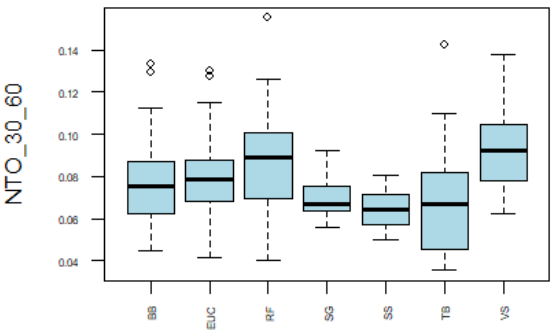
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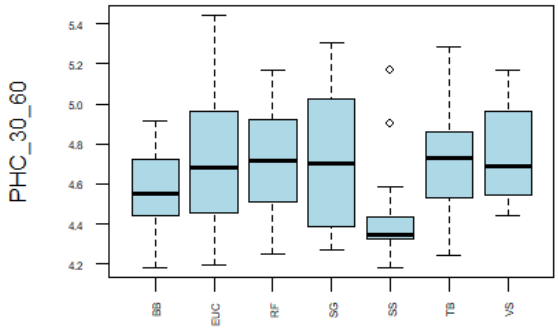
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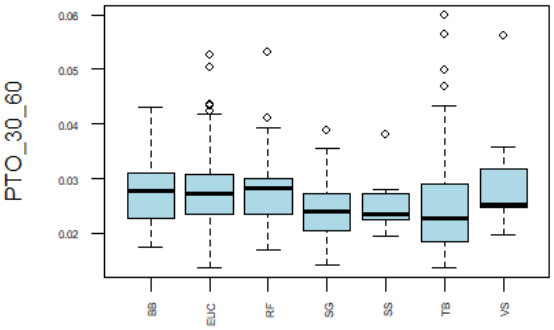
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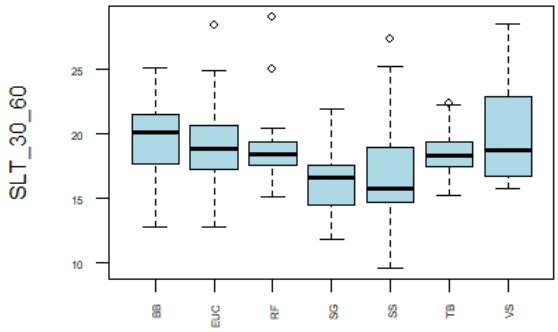
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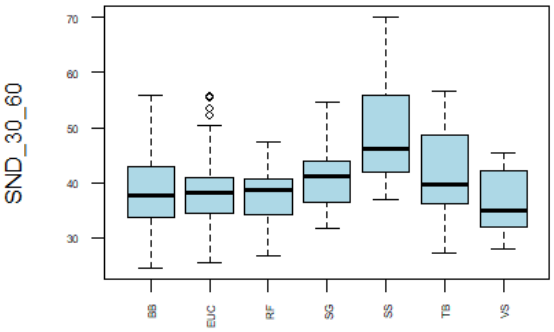
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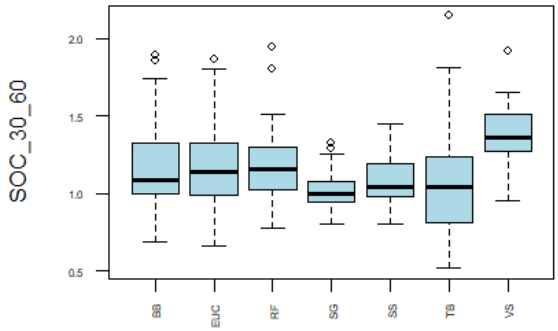
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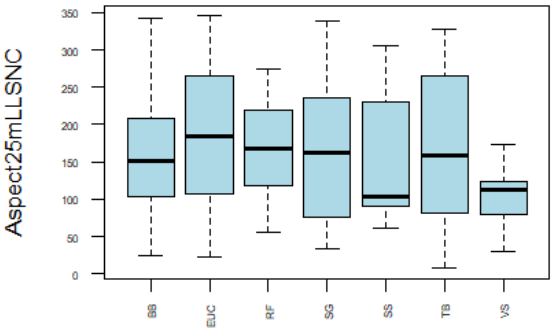
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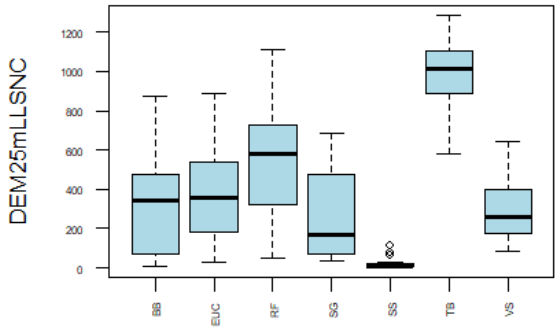
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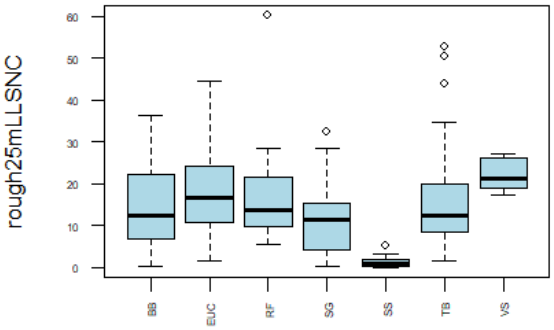
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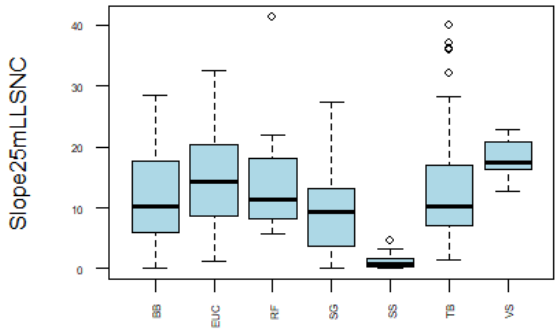
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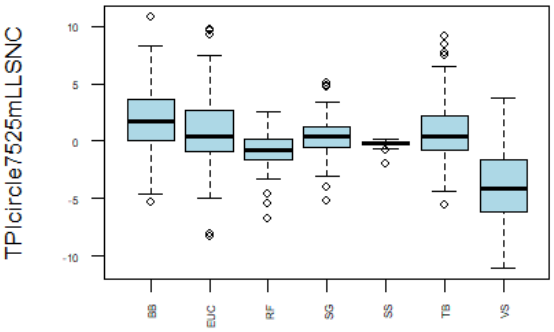
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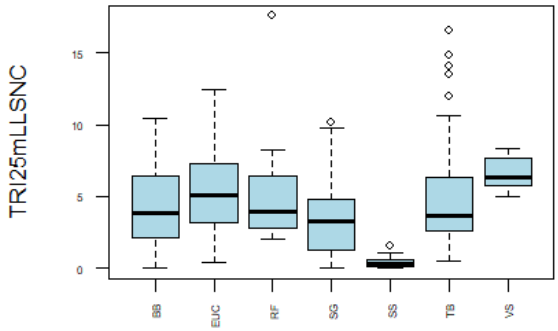
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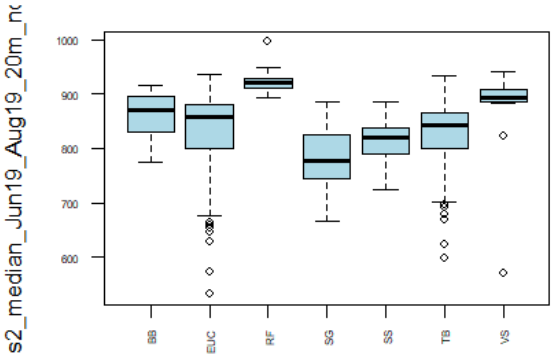
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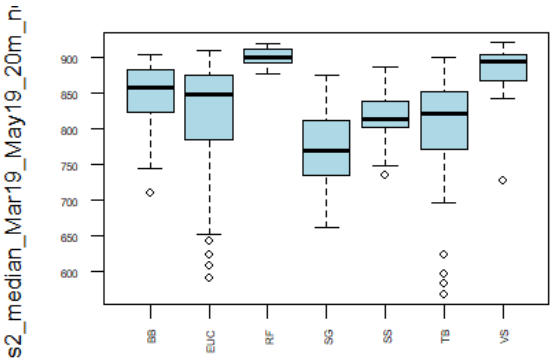
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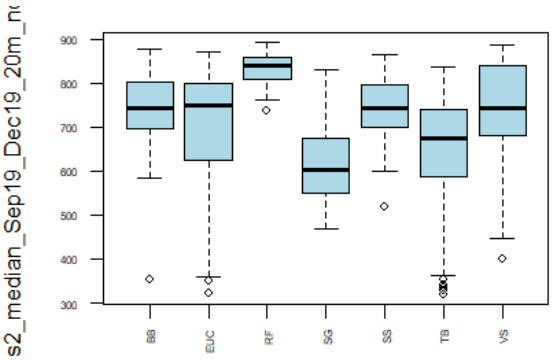
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Appendix C

South Coast YAG classification

YAG 1 Moist Coastal (Sclerophyll) Forest

Along this section of the NSW coast, there is a gradient from 'subtropical' to 'temperate' – see Biogeographic Regionalisation of Australia.

YAG 1 is almost always found on sites that have high moisture availability and fertility, i.e. southerly/southeasterly slopes on more fertile geological substrates.

The height of mature trees is almost always over 40 metres.

Broad-leaved, shorter trees and shrubs are almost always present and can form a dense continuous layer with relatively broad, horizontally oriented leaves below the sclerophyll canopy.

This is likely to result in low penetration rates of Lidar to the ground.

Where overstorey cover is low: Lidar will have a low proportion of tall hits; and the relatively high reflectance from the sub-canopy will increase Infrared and green.

YAG 2 Spotted Gum

YAG 2 has a coastal distribution within Southern PNF;

most observations are within a large population north of Moruya, and a smaller population south of Bodalla, with scattered observations further north and south.

Spotted Gum occurs on a range of topographic positions excluding extreme slopes e.g. poor drainage, very steep northerly slopes

Florence (2004) reported that the presence of calcium in soils is correlated with Spotted Gum occurrence. Therefore, distribution may be more strongly influenced by geology and soil, more than topography.

Mature tree height is usually from 25 m up to 50m.

From an aerial photo interpretation perspective, mature Spotted Gum tends to have distinct, large, light green, rounded crowns compared to other sclerophyll tree species.

A Lidar Point cloud metric that correlates with shapes within the forest canopy e.g., presence of broad spherical domes, may be useful.

Spotted Gum forest within State Forest is likely to have been subject to selective harvesting.

YAG 3 Silvertop Ash

YAG 3 is distributed primarily along the coastal ranges with smaller populations on the tablelands east of the Great Dividing Range.

Maximum prevalence of YAG 3 is in the southeast corner.

Topographically YAG 3 is commonly on or close to ridge-lines, appears to favour soils that good drainage with lower fertility.

Very similar topographic positions can be occupied by YAG 4, with geology/soil (fertility and moisture) likely to be correlates.

From an aerial photo interpretation perspective, mature Silvertop Ash is distinguished by a lack of distinct tree crowns. The forest canopy appears as a continuous layer of leaf-bundles.

Lidar point clouds may be able to detect the lack of variation in height and absence of three-dimensional shapes within the canopy.

Areas dominated by Silvertop Ash appear red when there is an episode of foliage growth. This is periodic, but due to seasonal variability would not occur every e.g. spring.

It may be that when a spike plant foliage growth occurs across the landscape, Silvertop Ash may be correlated with a coincident increase in red reflectance.

Significant areas of Silvertop Ash forest have been harvested with very high levels of canopy removal, followed by regrowth. The characteristic red appearance is does not return for at least a decade, when the growing leaves dominate reflectance.

YAG 4 Coastal Dry Forest

YAG 4 occurs on ridges and West-North-East facing slopes (i.e., not “protected”) areas usually east of the escarpment,

It can be considered the default in those topographic situations, i.e., where single species YAGs are not present.

Mature height range is about 25 to 35 metres.

It can merge into YAG 8 Low Productivity Forests on low fertility soils and sites with extreme moisture characteristics, and YAG 2, 3 or 5 on higher productivity sites.

Many sites will have been selectively logged during the satellite imaging period.

YAG 5 Yellow Stringybark – Gum

Yellow Stringybark – Gum occurs on moist protected south/south-easterly slopes on relatively fertile soils.

Distribution is concentrated in the southeast and north to Bateman’s Bay, with lower frequency further north.

It “replaces” YAG 1 Moist Coastal Forest on similar aspects, probably due to the temperature gradient from north to south, corresponding to sub-tropical to temperate climatic classification.

Mature YAG 5 is usually over 40 m in height.

Mature YAG 5 tends to have large distinct crowns.

It merges with YAG 4 and YAG 3 upslope, YAG 14 where poorly drained creek/valley flats support forested wetland, and YAG 6 in the west where cooler conditions begin to dominate.

YAG 6 Brown Barrel – Messmate

YAG 6 distribution overlaps to Yellow Stringybark – Gum, preferring moist protected aspects and higher fertility soils.

The main difference being that YAG 6 occurs in cooler areas, at higher elevations in the north, but in the far south it can occur close to sea level. This may be due to cold-air drainage, and highlights the fact that temperature is a major driver of species distribution rather than “tablelands” or “coastal” definitions.

Distribution within the project area is mostly along the coastal escarpment and further west to the Great Dividing Range, with only a few occurrences further west.

YAG 6 forms tall forest with mature height about 35 to 60 m, typified by large rounded dark green crowns when mature.

YAG 7: Gum – Peppermint

YAG 7 is found in cool-temperate climatic areas, which is generally on the tablelands, but includes areas close to the coast further south.

It also occurs in sub-alpine areas west of the Great Dividing Range

Topographically it occurs on south-south-easterly slopes, and along drainage lines, where it may merge with YAG 14.

It is frequently adjacent YAG 12 (in the west), YAG 6 and YAG 5, perhaps controlled by temperature, moisture availability, and lower soil fertility.

YAG 8: Negligible Timber Value

YAG 8 refers to eucalypt forest and woodland that is of little value for timber production.

Distribution of YAG 8 is restricted to sites with impediments to growth of tall trees, e.g., very low fertility soils, heavy frost/snow, impeded drainage/waterlogging, skeletal soils, very cold or very hot etc.

These conditions tend to be in topographically extreme situations, e.g., steep slopes, northerly aspects, and valley floors, and on low fertility geological substrates, e.g. sandstone.

YAG 9: Rainforest

YAG 9 varies from sub-tropical rainforest in the north to cool-temperate rainforest in the south.

Subtropical rainforest has a more complex structure and is taller than cool-temperate rainforest, which can be dominated by a single species.

It occurs in areas that are protected from fire, which frequently are steep-sided gullies.

In the north, it is also associated with high-fertility basalt-derived soils.

YAG 9 reflectance is likely to be relatively high in the infrared and green bands due to broad horizontal leaves.

YAG 10 Non-Eucalypt Forest (also non-rainforest)

There are 16 YAG 10 observations.

They are either: areas that have been cleared then opportunistically populated by wattles

or, areas with a more natural occurrence of Casuarina or Callitris, which are usually on exposed topographic positions or very low fertility, dry sites.

YAG 11: Non-Forest

There are very few YAG 11 observations because the area to be mapped targets forested areas.

YAG 12: Alpine Ash

YAG 12 is restricted to sub-alpine areas west of the Great Dividing Range, at altitude ranging from about 1000 to 1500 metres.

A large majority of YAG 12 is reserved as State Forest.

It occurs on protected southerly topographic positions.

Alpine Ash has a distinct brown/red colour.

Alpine Ash forest can be totally killed by fire, which then regenerates subject to seed availability.

Fire events in 2001/2002, 2002/2003 and 2019/2020 resulted in complete mortality of some patches of YAG 9.

YAG 13 Blackbutt

Blackbutt is an insignificant proportion of the project area.

YAG 13 has been included as a separate because of the potential to cause misclassification in modelling.

For each YAG 13 observation an alternative has been included (YAG_24).

It may be that YAG 13 observations can be assigned to YAG 1, 2, or 4 based on height.