Department of Primary Industries

North Coast Residues

A project undertaken as part of the 2023 North Coast Forestry Project

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Contents

Executive summary

The main purpose of this project was to determine the potential availability of forestry residues for bioenergy generation and other applications on the North Coast of NSW, for three main regional "hubs": Bulahdelah, Kempsey and Grafton. The provision of field-based information on residue availability and any potential impacts of extraction support the long-term sustainability of the native forest industry on the NSW north coast. The dramatic reduction in the demand for pulp logs in the region since 2013 has increased wastage and operational challenges (e.g. increased fuel loads); limited forest management options (by reducing thinning opportunities), and reduced profit margins.

For the purpose of this report the residue available in native forests (public and private) is limited to logs meeting pulp specification only, the bulk of which is currently left in the forest as harvest residue, though when assessing ecological sustainability all coarse woody debris is considered. We have estimated the available biomass from residues generated from integrated harvest operations which target the production of high-value logs (e.g. sawlogs, poles). For plantations, "pulp logs", as well as "total residues" (option of in-field chipping) were considered. For sawmills, all "green" residues were considered potentially available for bioenergy generation.

Total available green harvest residue (within 100 km radius of the hubs) ranged from approximately 186,000 tonnes for Bulahdelah to 464,000 tonnes/year for around Grafton. The total estimated volumes for the North Coast are close to one million tonnes. These figures, though based on best available knowledge and field measurements, are indicative only, and may vary considerably, especially in the case of volumes estimated within 50 km of the hubs. Harvest residues from public native forests were highest around Bulahdelah and Kempsey (100 km radius), whereas private native forest residues were highest around Grafton. Volumes of hardwood plantation harvest residues were especially high for Grafton. For plantation softwoods, increasing the radius to 150 km would substantially increase the volumes of residues available, as the radiata pine stands in the Walcha region would then be captured.

The physical properties of key native forest hardwoods in each of the hubs were determined; average moisture content and basic density of the "pulp-quality" biomass was 38% and 710 kg/m^3, respectively. The calorific value of samples collected from a range of hardwoods did not vary greatly, ranging from 18.6 Mj/kg for blackbutt to 19.3 Mj/kg for red mahogany.

Sawmill residues (green) were estimated to range between 46,000 tonnes for around Bulahdelah to 118,000 tonnes/year for facilities around Kempsey (100 km radius). Green offcuts represented approximately 68% of the total volume of green residues produced. Current markets for some of the green residues vary depending on location; the power/heat market is stronger further up North, whereas landscaping markets are strong for processors within 150km of Bulahdelah, especially those closer to Sydney.

Additional important sources of biomass include residues from agricultural crops (45,000 -78,000 tonnes/year) and waste currently disposed of in landfills (approximately 700, 000 tonnes/year).

Preliminary estimates from the residue valuation work suggest that the average weighted costs (delivered prices) for biomass in the form of woodchips from harvest operations and sawmills range from $48/tonne of chips for biomass within 50 km of Kempsey, to $67/tonne of chips for biomass within 150 km of Bulahdelah. These values include native and plantation forest residue volumes and mill residues. When mill residues are excluded weighted average prices increase, typically ranging between $58 and $70/tonne of chips.

The forestry biomass available is significant and certainly enough to support the development of large and small scale bioenergy generation systems. This would include for example at least six average-sized pellet production facilities (producing 100,000 tonnes of pellets / year), with enough combined electricity generation potential to supply annual electricity needs of over 200,000 homes in NSW. The use of biomass to produce heat in smaller scale generation systems (e.g. boilers for heating public pools) is also an option – a typical sized system of 600 kW capacity requires approximately 600 tonnes of woodchips for six months.

There is growing interest worldwide in the potential for bio-chemical production from tree biomass. Preliminary chemical profiling work revealed the presence in tallowwood and flooded gum of significant quantities of gallic acid and catechin, which are chemicals with potential industrial and therapeutic applications. We estimate that approximately 2 – 3.5 kg of these compounds would be available in the logs meeting pulp specification for an average mature tallowwood or flooded gum tree.

One of the common concerns raised in utilising native forest biomass for bioenergy generation, is the impact on sustainability, including concerns over nutrient depletion, biodiversity and climate implications.

Removal of additional biomass for bioenergy from native forests will result in increased loss of nutrients (typically greater for nitrogen); however the nitrogen lost is largely expected to be replenished naturally during the longer native forest harvest cycles. Generally the nutrient concentration in leaves was higher than for other biomass fractions, with the exception of calcium, which is more concentrated in the bark. It is considered that net losses of phosphorus due to harvesting are inevitable – however, this may be a very long-term proposition for native systems with longer rotations than plantations– decline in productivity due to phosphorus or any other nutrients has not been demonstrated for native systems. Retention and management of bark on site, retention of leaves and minimising post-harvest regeneration burns are identified as key actions to minimise any impacts on nutrient availability due to extraction of biomass.

The biodiversity component of the research confirmed expectations that managed native forests on the north coast typically support higher volumes (~ 2 x) of CWD than unmanaged forests, mostly resulting from more pieces of smaller material. Harvest frequency was also related to higher volumes of CWD. These benchmarking results can be used to provide guidance on 'natural' levels of CWD and the surplus produced by harvesting. Use of camera traps revealed the importance of CWD as habitat for a diversity of species. From a habitat provision perspective, large CWD pieces, especially those with a hollow, appear most important. Finally, preliminary assessments of the responses of bats and birds before and after thinning young regrowth (a potential source of residue) revealed mostly neutral to positive responses.

Although many studies demonstrate the GHG benefits of using forestry residues for energy generation, others argue that this practice does not result in GHG benefits, with some claiming worse outcomes than the use of coal for electricity generation. The greenhouse gas balance carried out here clearly shows that, from a climate perspective, using biomass that would have otherwise been left in the forest to burn and/or decay for bioenergy generation results in positive outcomes, especially if biomass is used to produce electricity displacing the use of coal. This is true even when the carbon dioxide emissions from burning the biomass to generate energy are included in the calculations. In practice, the CO2 released will be reabsorbed by the growing trees in a sustainable harvest system, eventually negating the impact of such emissions.

The key aim of this project was to provide information on the extraction of forestry biomass for bioenergy and other applications on the NSW North Coast, so that potential investors can have greater confidence in the residue availability for each of the hubs. The analytical framework now in place allows the derivation of potential available volumes in the vicinity of any major regional town of interest in the North Coast. Further work is required to determine residue availability in other important native forest wood-producing areas of the State, such as the south coast and western region, to continue supporting the creation of new markets for forestry biomass from sustainably managed forests.

Background

The North Coast of NSW has a long history of managing forests for multiple objectives, including timber extraction. The types of logs extracted are largely dependent on market conditions. Since 2013 the demand for pulp logs has decreased dramatically, resulting in large volumes of biomass left in the forest following extraction of high-value logs. In addition to increased wastage, the loss of this market has had a number of other important ramifications. The increased levels of harvest residues left in the forest are limiting future access and increasing operational risks (e.g. managing fuel loads). The management of hardwood plantations has been constrained as silvicultural thinning has become largely uneconomic, and the profit margins for wood processors have reduced in the absence of an export woodchip market.

As a consequence of the June 2014 Cabinet decision on the 2023 North Coast Forestry Project, The NSW Department of Primary Industries (DPI) has been charged with the scoping, management and delivery of three strategically-aligned R&D projects. The purpose of these projects, which were funded by the NSW Department of Industry DPI, were to provide scientifically-sound information that will support the long-term sustainability of the native forest industry on the NSW north coast. Determining the potential availability of forestry residues for bioenergy generation and other applications was identified as one of the priority projects.

More recently, one of the key actions identified in the NSW Forest Industry Roadmap under the Pillar “Industry innovation and new markets”, is the “identification of new markets for forest products with a focus on the low carbon economy”. Recent legislative developments may assist in providing the necessary impetus for alternative markets such as bioenergy and high-value chemicals to be developed. These include:

• The change in legislation in NSW allowing the burning of native forest wood waste for electricity generation;

• The change to the Renewable Energy Target (RET), which has reinstated native forest wood waste as an eligible renewable energy source;

• The previous clause that precluded Carbon Farming Initiative (CFI) projects from using native forest biomass has been removed under the Emissions Reduction Fund (ERF).

There is currently limited reliable information on the volumes of different types of forestry residues produced, and also limited understanding of the spatial availability of the biomass in relation to key regional centres. This is important as transport costs are often the main reason projects aimed at utilising harvest residues are deemed financially unviable.

There is also limited information on the maximum level of forest biomass that could be sustainably supplied from NSW native forests without adversely impacting on forest nutrition and biodiversity, although it is known that fallen logs provide critical habitat for a range of species. From a life-cycle perspective it is important to determine the GHG implications of increasing the use of renewable energy in the form of native forest harvest residues so that concerns regarding the climate implications of such extraction can be addressed.

The development of a new bioenergy / high value chemical industry on the NSW north coast is dependent primarily on reliable information on available biomass, knowledge of sustainable levels of utilisation including potential environmental impacts, and knowledge of available technologies that offer the best “fit for purpose” options. This project has attempted to address these questions, with the ultimate aim to provide confidence to prospective investors interested in the use of forestry residues.

1. Residue availability: forest harvest

Fabiano Ximenes, Rebecca Coburn, Michael McLean

In this and the following chapters we include key information derived from the project. There is a large volume of additional data that is not included in this report for the sake of brevity, but which can be made available to interested parties on request. It is our intention to progressively publish much of this additional information in peer-reviewed journals.

1.1 Forest types

Residue availability from forests was estimated for three key regional hubs on the North Coast of NSW, namely Buladelah, Kempsey and Grafton. The hubs were selected in consultation with industry, primarily on the basis that they are traditional timber regional communities and they span the range of forest types and markets present on the North Coast. The work detailed in all the sections below refers primarily to residues available around those hubs. The forest types of the North Coast were grouped into six broad forest types based on FCNSW's yield association groups (Figure 1.1). The geographical boundaries set for the study are included in Figures 1.3-1.5.

The estimated residue volumes for each of the hubs took into account a range of distances (50, 100 and 150 km) between the biomass source and the location of a biomass-processing facility (assumed to be located at the centre of each of the hub locations).

1.2 Forest harvest residues

1.2.1 Native forests - Public

For native forests, residue estimations were conservative, as we only considered logs that met the specifications for pulpwood as available for extraction (typically 10 cm small end diameter overbark, and a minimum of 2.5 m in length – no species restrictions – and the crown was typically left in the forest). This was partly due to the fact that the local industry already has experience harvesting and transporting pulpwood from the forest. Extracting pulpwood only, means that a significant proportion of the residues generated (stump, bark, leaves, small branches, large and defective stem sections) are left in the forest, helping mitigate impacts on biodiversity (Chapter 6) and future nutrition needs of the forests (Chapter 5). We have estimated biomass from residues generated from planned integrated harvest operations which target the production of sawlogs, poles and salvage logs.

The derivation of the "pulp potential" for the various forest types in each hub was carried out in close consultation with the Forestry Corporation of NSW (FCNSW) and involved many different harvest contractors. The general approach was to identify a patch of forest within a compartment being harvested as being "typical" of that forest type (Table 1.1). A 0.5 ha plot was established, where all trees were individually measured (DBH and height) and identified to species. Working within the prescriptions of the harvest plan, the contractors harvested the plot as they routinely would but with the additional requirement to extract logs that met pulp specifications. The logs were then either weighed directly (Figure 1.2) or measured. This data was used to derive pulp factors on a hectare basis (Table 1.1) as well as pulp to sawlog ratios for each forest type. These factors were used to estimate the residue potential for the hubs. Ultimately the derivation of the harvest residue data was based on a combination of recent log sales data, analysis of GIS information, the field trials described above and extensive consultation with FCNSW staff. The recent annual average log production was used as one of the factors to predict residue availability. This assumption was adopted in consultation with industry, as it was deemed that recent levels of harvest are likely to remain relatively constant in the short to medium term.

Many of the factors used may carry a significant degree of uncertainty, given the complexity of forest types, diversity of datasets used and limited sampling size. Thus the volumes provided here should be seen as indicative of the potential.

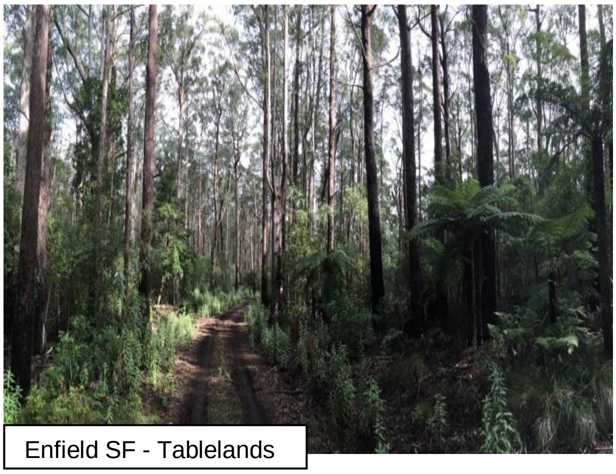
Figure 1.1 Examples of the six forest types used for this study

High productivity

Comboyne SF – Moist blackbutt

Newry SF – Dry blackbutt

Medium productivity



Enfield SF - Tablelands

Wang Wauk SF – Moist coastal eucs

Low productivity

Mount Marsh SF – Spotted gum

Ballengarra SF - Semi-moist / dry

Table 1.1 Location, forest type and residue of the field sites (Important to note that the residue values are a reflection of the standing volume, site quality and forest type of each site).

Forest type	Hub	State forest	Residue tonnes/ha
Moist Blackbutt	Buladelah/ Kempsey	Comboyne	132
Moist Blackbutt	Kempsey/ Grafton	Orara West	129
Moist Coastal Eucalypts	Buladelah/ Kempsey	Comboyne	144
Moist Coastal Eucalypts	Bulahdelah	Wang Wauk	146
Moist Coastal Eucalypts	Bulahdelah	Chichester	109
Moist Coastal Eucalypts	Kempsey/ Grafton	Moonpar	79
Dry Blackbutt	Kempsey	Tamban	33
Dry Blackbutt	Kempsey/ Grafton	Newry	26
Dry Blackbutt	Grafton	Clouds Creek	39
Spotted Gum	Grafton	Mount Marsh	58
Spotted Gum	Grafton	Bungawalbin	68
Semi Moist & Drier Types	Kempsey	Bulls Ground	84
Semi Moist & Drier Types	Kempsey	Ballengarra	105
Tablelands	Grafton	Moogem	82
Tablelands	Kempsey	Enfield	50
Tablelands	Kempsey	Styx River	66

Figure 1.2 Weighing biomass in the field

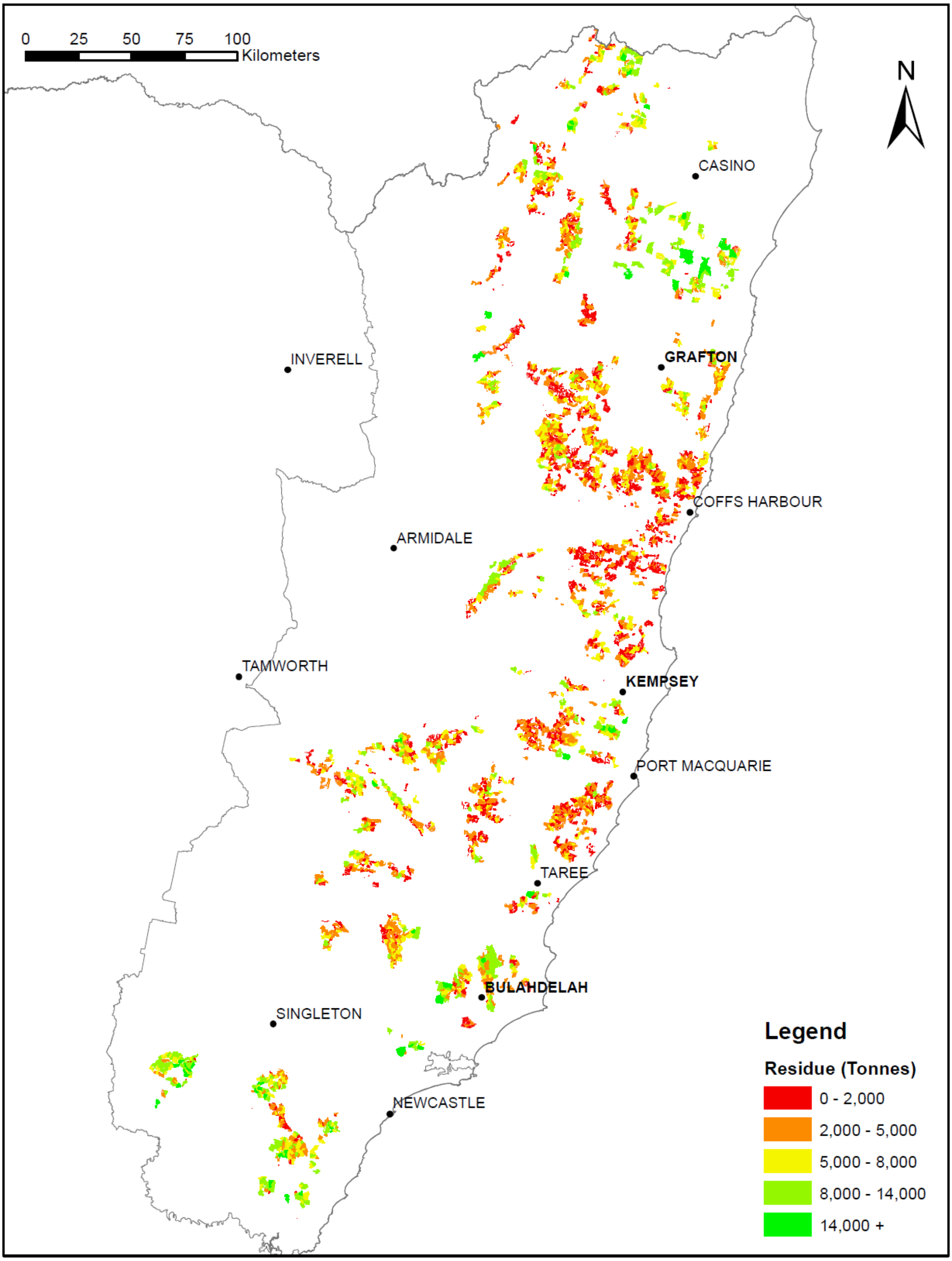
The estimated residue generation for varying distances from the three regional hubs is presented in Table 1.2.The values assume that a substantial proportion of the biomass (typically at least 20% of the total biomass) is left in the forest after harvest. The totals range from a minimum of around 36,000 tonnes of harvest residues for forests in a 50 km radius from Bulahdelah, to 260,000 tonnes of biomass for forests in a 150km radius from Kempsey (Table 1.2). The total residue generation for the North Coast (approximately 400,000 tonnes) is lower than the sum of residues for all the hubs. This is because there is overlap of the hubs at 100 and 150 km radius. The estimated high quality log volumes (quota sawlogs, poles, girders) for each of the hubs is also included – these are invariably lower than residue volumes (Table 1.2).

Table 1.2 Native forest harvest residues (tonnes); Residue estimation using an estimated annual high quality log (HQL) volume and a residue to HQL ratio derived from a combination of field data and sales/ harvest data.

Native forest residues – distance from hubs	**Bulahdelah**		**Kempsey**		**Grafton**	
	HQL (m^3)	Residues (tonnes)	HQL (m^3)	Residues (tonnes)	HQL (m^3)	Residues (tonnes)
50 km	15,483	36,497	30,191	55,607	29,337	64,665
100 km	42,319	88,427	89,202	150,187	94,052	174,855
150 km	77,673	162,848	139,113	260,026	118,574	229,500

Figure 1.3 shows the spatial distribution of the potential residue within the public native forest estate for the NSW North Coast. It provides an indication, for a given area of forest, of the likely residue volumes generated at the time of harvest after removing mapped exclusions such as steep slopes and old growth and also areas of forests more heavily harvested in the last 10 years.

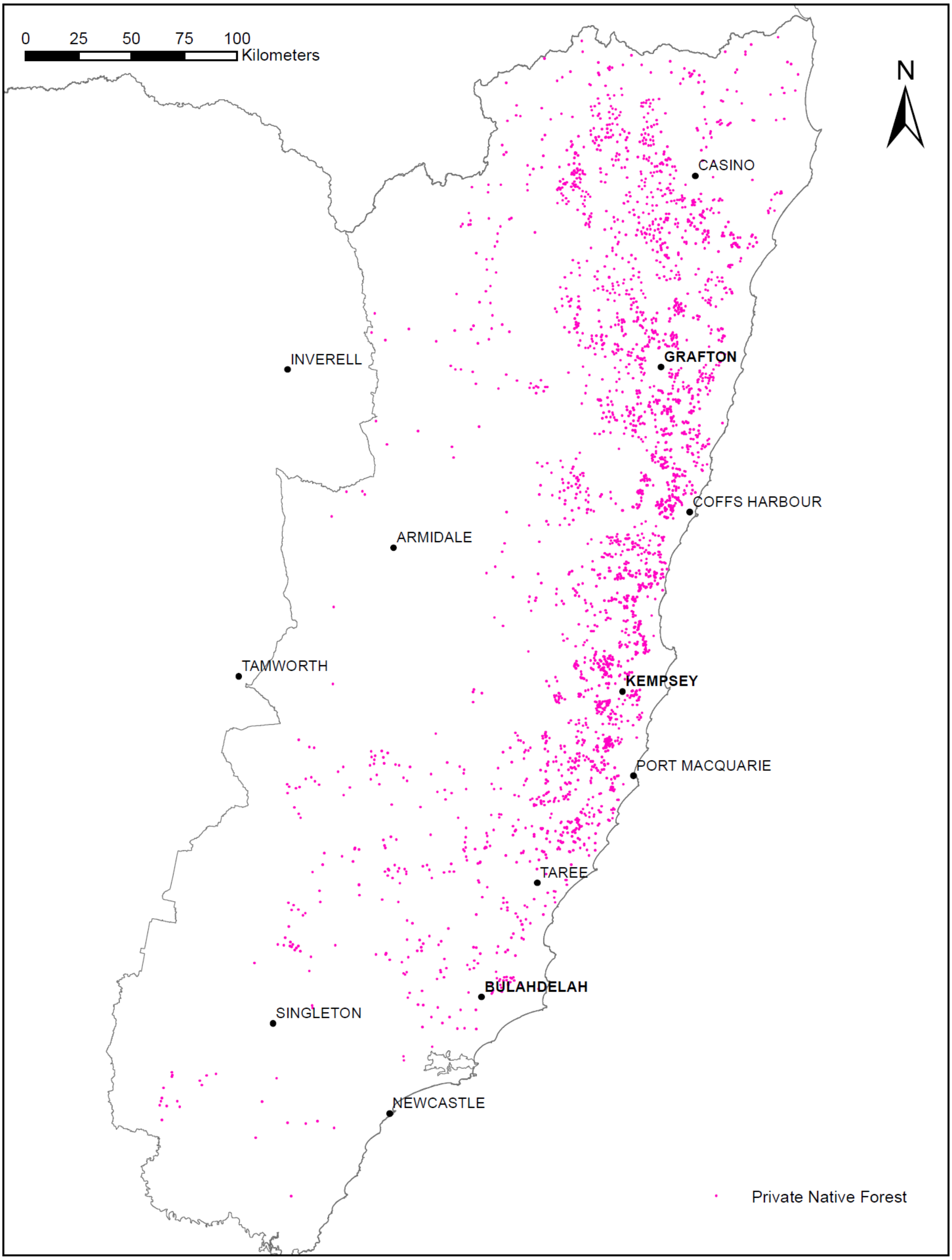
Figure 1.3 Residue generation potential of the public native forest estate on the NSW North Coast



1.2.2 Native forests - private

The NSW North Coast has around 2.9 million hectares of private native forests spread across over eighty thousand individual properties. 2,745 properties covering over 400,000 hectares currently have an approved PVP plan to harvest native timber (Figure 1.4)

Figure 1.4 Private native forests with an approved Property Vegetation Plan (PVP)



The annual volume of sawlogs (quota and salvage) from private properties is around 275,000 m^3, with high quality logs (quota and poles) accounting for 158,000[1] m^3. This value was derived from surveys of harvest contractors and also surveys of wood-processing facilities. The estimated volume of residues generated from native forest harvesting on private properties is included in Table 1.3. The values were derived based on information from the surveys, current approved Property Vegetation Plans (PVP), forest type mapping of private properties and the residue to sawlog ratios developed from the public estate. The majority of the resource is situated around the Grafton hub (Table 1.3). The total estimated volume of residues generated from private forestry operations on the North Coast (approximately 393,000 tonnes) is similar to that of public native forests.

Given the large number of private properties undertaking harvest operations, a biomass “broker” may be required to organise the potential sourcing of the biomass for a bioenergy market.

Table 1.3 Private native forest harvest residues (total residues, tonnes,); Residue estimation using an estimated annual high quality log (HQL) volume from contractors surveys, and a residue to HQL ratio derived from public native forests. This volume was apportioned across the hubs and different radii based on the approved PVPs.

Private Native forest residues – distance from hubs	**Bulahdelah**		**Kempsey**		**Grafton**	
	HQL (m^3)	Residues (tonnes)	HQL (m^3)	Residues (tonnes)	HQL (m^3)	Residues (tonnes)
50 km	9,459	23,160	12,621	30,353	42,566	111,552
100 km	29,954	71,574	37,836	88,547	81,978	209,731
150 km	42,566	101,862	66,213	159,939	104,050	264,229

1.2.3 Plantations

Figure 1.5 shows the current location of public hardwood and softwood plantations on the NSW North Coast. There are approximately 35,000 ha of hardwood plantations, with the majority of those (around 63%) planted post 1994. The northern hardwood plantation resource occurs in a large number of relatively small blocks predominantly on the coastal lowland between Newcastle and the Queensland border, with the majority of the area planted between 1996 and 2004. The earlier plantings are of variable quality, largely due to large establishment targets being achieved in a short time-frame. The main species planted were Blackbutt (*Eucalyptus pilularis*), Dunn’s White Gum (*Eucalyptus dunnii*), Flooded Gum (*Eucalyptus grandis*) and Spotted Gum (*Corymbia maculata*).

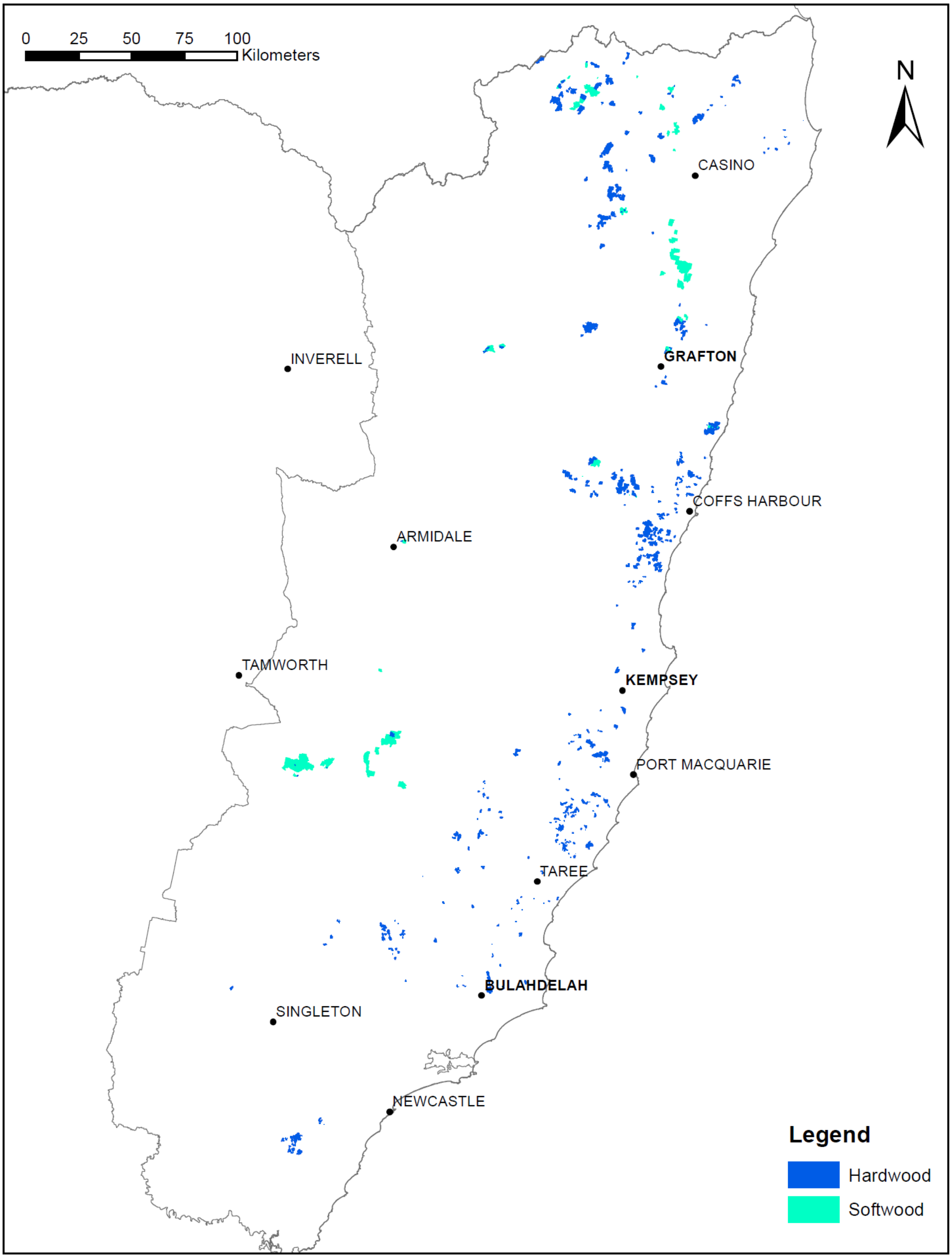
The softwood estate has a more confined distribution focused around Grafton and Walcha (Figure 1.5). Key species planted include radiata pine (*Pinus radiata*) and southern pine (*P. elliottii var. elliottii, P. taeda* and *P. Caribaea var. hondurensis*). There are approximately 12,000 ha of radiata pine plantations around Walcha and 16,000 ha of southern pine around Grafton.

For plantations, residue estimation is based on recent harvest history and modelling provided by Forestry Corporation of NSW (as was the case for Grafton) (Table 1.4 & Table 1.5). Residue

[1] Volume based on 2017 North Coast surveys of PNF Contractors and Primary Processors

estimates based on recent harvest history are unlikely to be indicative of residue generation in the future (most likely underestimating potential), as the management of the plantations is evolving. Factors such as the development of a comprehensive thinning program and the presence of a strong market for biomass for bioenergy would have a significant impact on biomass generation.

Figure 1.5 Location of public hardwood and softwood plantations on the NSW North Coast



The residue estimate is apportioned across the hubs based on their proportion of the total area or of total sawlog volume. The analysis also took into account whether only “pulp-quality logs” are extracted or whether the non-sawlog biomass is chipped on site. For plantations, it may be more economical to chip all residues on site and manage potential future nutritional deficiencies by the addition of fertilisers.

For softwoods, the values range from no residues available within a 50 km radius from Bulahdelah and Kempsey, to 70,000 tonnes within a 150 km radius from Bulahdelah. For plantation hardwoods, the values range from 4,500 tonnes of residues available within a 50 km radius from Kempsey, to approximately 140,000 tonnes within a 150 km radius from Grafton.

Table 1.4 Softwood plantation harvest residues- including some thinnings (total residues, tonnes); Bulahdelah and Kempsey estimates are based on recent harvest history, Grafton is based on FCNSW modelling

Softwood plantation distance from hubs	**Bulahdelah**		**Kempsey**		**Grafton**	
	Pulp (tonnes)	All Residues (tonnes)	Pulp (tonnes)	All Residues (tonnes)	Pulp (tonnes)	All Residues (tonnes)
50 km	0	0	0	0	7,837	17,242
100 km	0	0	78	218	10,962	24,117
150 km	31,930	70,529	18,318	41,471	16,245	35,740

Table 1.5 Hardwood plantation harvest residues (total residues, tonnes); Bulahdelah is based on recent harvest history, Kempsey and Grafton are based on FCNSW modelling.

Hardwood plantation distance from hubs	**Bulahdelah**		**Kempsey**		**Grafton**[1]	
	Pulp (tonnes)	All Residues (tonnes) – field chipping	Pulp (tonnes)	All Residues (tonnes) – field chipping	Pulp (tonnes)	All Residues (tonnes) – field chipping
50 km	4,814	7,000	4,507	6,435	13,027	19,765
100 km	18,968	27,815	22,819	32,920	55,019	79,070
150 km	31,482	45,655	43,249	63,000	98,011	139,956

[1] Includes biomass from thinning operations

Table 1.6 includes the current volumes of residues available for the North Coast of NSW from all forest types within 100 km of each of the study hubs. Although it is important to express biomass values in green tonnes, for energy generation it is important to determine what the dry content of the biomass is.

The estimated values differ in the level of confidence, with estimates for the native public estate likely to be the most accurate. For plantation softwoods, increasing the radius to 150 km would substantially increase the volumes of residues available (Table 1.4), as the radiata pine stands in the Walcha region would then be captured.

Table 1.6 Forest harvest residues – summary (residues available for extraction, tonnes within 100 km radius from each hub)

Residue type	Bulahdelah		Kempsey		Grafton		North Coast	
	Wet (tonnes)	Dry (tonnes, 0% moisture)	Wet (tonnes)	Dry (tonnes, 0% moisture)	Wet (tonnes)	Dry (tonnes, 0% moisture)	Wet (tonnes)	Dry (tonnes, 0% moisture)
Native public	88,427	54,825	150,187	93,116	174,855	108,410	399,958	247,974
Native private	71,574	44,376	88,547	54,899	209,731	130,033	392,655	243,446
Hardwood Plantation CF (field chipping)	27,815	15,576	32,920	18,435	79,070	44,279	185,612	103,943
Softwood Plantation CF (field chipping)	-	-	218	109.0	24,117	12,059	106,269	53,137
Total	**187,816**	**114,777**	**271,872**	**166,559**	**487,773**	**294,781**	**1,084,494**	**648,500**

1.3 Additional sources of biomass

In addition to the forestry feedstocks described above, there may be additional biomass associated with managed investment scheme (MIS) plantations in the region. Though likely significant in volume, it would represent an opportunistic and short-term source of biomass. Residues from harvest in private hardwood plantations may also be significant in certain regions.

Finally, in Table 1.7 we include an estimate of agricultural cropping residues present in each of the hubs (within 100 km radius). This is important, as some bioenergy technologies are agnostic in relation to the type of biomass used.

Table 1.7 Availability of agricultural residual biomass

	Cereal Straw	Non-cereal Straw	Hay	Total Silage	Total
Grafton	6,133	6,696	13,197	19,250	45,276
Kempsey	514	400	11,345	35,608	47,866
Bulahdelah	2,317	411	40,678	34,216	77,622

Cereal straw can be produced from a variety of sources (e.g. wheat, barley, rice, oats), whereas non-cereal straw is primarily derived from oilseeds, pulses and canola. Hay is defined as grass, legumes or other herbaceous plants that has been cut and dried for use as animal fodder. Silage is usually made from grass crops, including maize, sorghum or other cereals, using the entire green plant (not just the grain). It is compacted and stored undried, in airtight conditions, typically in a silo, and used as animal feed. It can be fed to cud-chewing animals such as cattle and sheep or used as a biofuel feedstock for anaerobic digesters. Hay is considered to be more readily available and suitable for bioenergy applications as it is dried, stackable and more easily transported than silage.

The information provided here on non-forestry residues comes from a separate project that is mapping all significant potential biomass available for bioenergy in Australia. More information can be found at https://nationalmap.gov.au/renewables/. An additional resource (which is currently been quantified in detail) includes organic waste currently sent to landfills. Current estimates suggest that the total organic waste currently deposited in landfills on the NSW North Coast (municipal solid waste, construction and demolition and commercial and industrial landfills) is in the order of proximately 700,000 tonnes.

2. Residue availability: wood-processing facilities

John Samuel, Fabiano Ximenes

2.1 Background

In this component of the project we estimated availability of residues from wood-processing facilities in the NSW North Coast, assuming the same geographical boundaries as for the estimations of harvest residues. A key element of the assessment was a survey of processors of native hardwood. In wood-processing facilities, residues are defined as the by-product of wood processing. In many cases, at least part of the residue fractions are already committed to an existing market, such as horticultural applications, energy generation and as feedstock for pulp or engineered wood product manufacture. For the purposes of this study, we have assumed that all "dry" residues from the dressing of dry timber and green sawdust are already committed to stable markets. We have assumed all "green residues" to be potentially available to a bioenergy market.

2.2 The Survey

The intent of the survey was to capture native wood processors on the North Coast of NSW processing >3,000m^3 logs /year. Residues arising from native timber sawmills generally are about 50% of log intake, with smaller sawmills (<3,000m^3/year) generally not producing sufficient residues nor having the residue handling or commutation systems for commercial sale. Additional information on the survey process and population and the actual survey form used are available. Of the population of 49 larger sawmills, 33 were interviewed; 8 refused to be interviewed, 5 were unable to be contacted and did not complete a postal survey, but were in business and 3 didn't refuse to be interviewed but did not complete a postal survey and could not be reached. 43 wood processors were excluded from the survey as they were:

1) believed to process less than 1,000m^3(4),

2) were mobile sawmillers and so residues would occur over multiple sites and generally they process less than3,000m^3/year (14),

3) the remainder exported logs, were out of business or no contact information could be found for them.

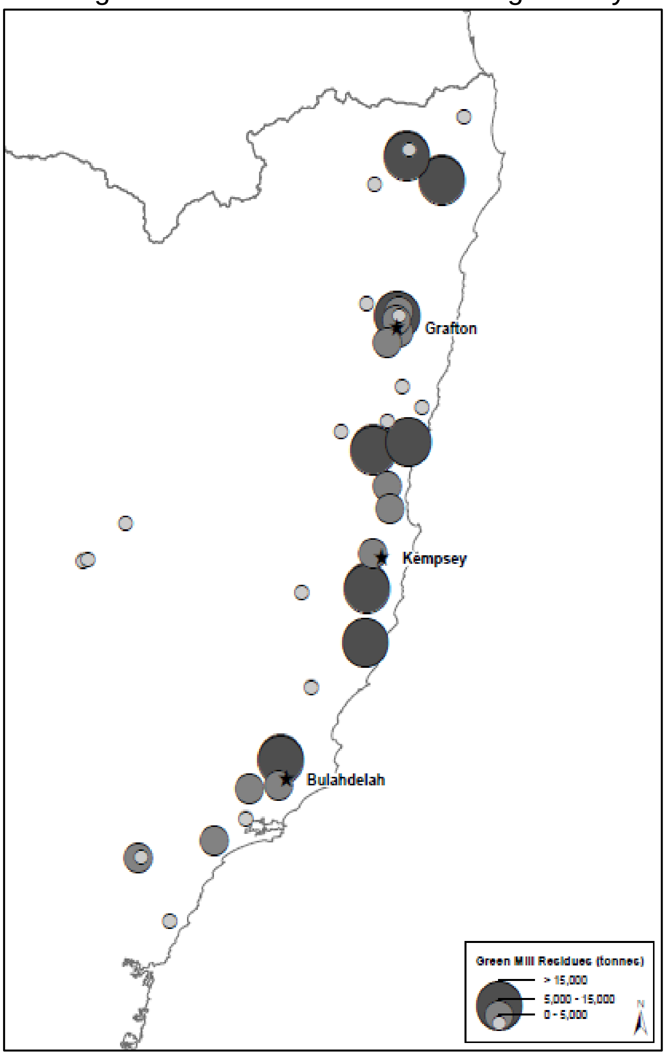


Figure 2.1 Map of the hubs and interviewed hardwood primary processors by calculated residue production

The key aims of the survey were:

- to assess volumes of logs processed from State Forests and private properties;
- determine levels of residues generated and their current use;
- to gain a better understanding of how residues are handled and perceived by sawmillers, and the potential opportunities and challenges associated with their use.

2.3 Summary results

In Table 2.1 we present the calculated residues generated from mills within varying distances from each of the study hubs. The private property (PP) sawlog volumes (quota and salvage) were derived from the survey responses, whereas the volumes of quota and salvage logs harvested from State Forests were provided directly by the FCNSW. Although specific questions on volumes of residues generated were asked in the surveys, there were inconsistencies with the data and also incomplete values were typically provided. Therefore, we applied recovery values from the literature[1 2,3] to estimate residue generation.

There is at least 40,000 tonnes of hardwood green residues arising from primary processors within 50 kilometres of road distance of each hub (Table 2.1). These values increase to in excess of 100,000 tonnes up to 150 km from each hub (Table 2.1). These values are conservative as they do not include residue generation from smaller sawmills (i.e. < 3,000 m^3/year log input).

Table 2.1 Calculated green residue production from primary processors for each hub

	Road distance	PP HQ & Salvage (Tonnes @ 1.2 t/m^3)	FCNSW HQ & Salvage (Tonnes @ 1.2 t/m^3)*	Green offcuts (Tonnes)	Sawdust (Tonnes)	Hearts / rotten (Tonnes)	**Total Residue (Tonnes)**
Bulahdelah	<50km	16,176	56,179	28,219	10,853	2,171	**41,243**
	50-100km	25,176	56,179	31,729	12,203	2,441	**46,373**
	100-150km	28,896	153,670	71,201	27,385	5,477	**104,063**
Kempsey	<50km	12,300	57,578	27,252	10,482	2,096	**39,830**
	50-100km	32,100	174,250	80,476	30,953	6,190	**117,619**
	100-150km	44,590	183,486	88,949	34,212	6,842	**130,003**
Grafton	<50km	24,196	82,818	41,735	16,052	3,210	**60,997**
	50-100km	31,716	88,657	46,945	18,056	3,611	**68,612**
	100-150km	97,565	177,013	107,085	41,187	8,237	**156,509**
	Softwood 50-100km		90,137	23,945	7,982		**31,927**
	Softwood 100-150km		201,534	53,547	17,847		**71,394**

* Primary processor FCNSW Av. Sales 2014/15 & 2015/16

Sawmills within 100 km from Kempsey produce the greatest volume of hardwood residues (117,000 tonnes); within 150 km Grafton has the highest volumes at 156,000 tonnes. If softwood residues are included, then Grafton has the highest tonnage of residues at all road distance groups (Table 2.1). Green offcuts account for 68% of the total green residues generated – this residue may be available in the "offcut" format or as woodchips in facilities that have wood-chipping equipment.

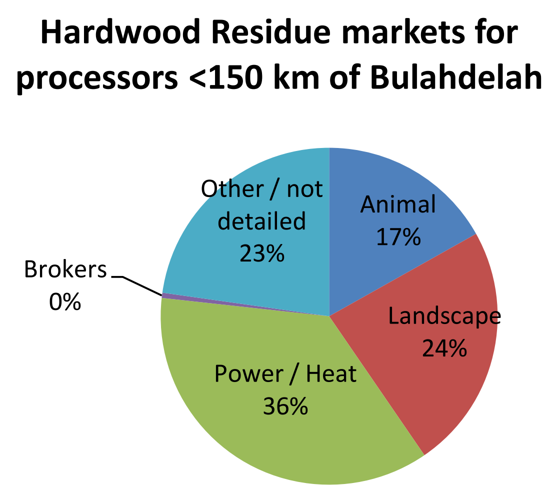
The current markets for hardwood residues are very different between hubs (Figure 2.2). Intermediaries or "middle men" are dominant in the Grafton market but hardly feature in the Bulahdelah residue market. They also are likely to supply into power/ heat market, potentially accounting for the shown difference in the size of this market between Kempsey and Grafton, as Grafton is much closer to the Cape Byron Power owned Broadwater and Condong biomass electricity plants. Intermediaries dominate the sawdust market in Grafton, principally suppling animal bedding. Landscape markets are strong for processors within 150km of Bulahdelah, especially those closer to Sydney.

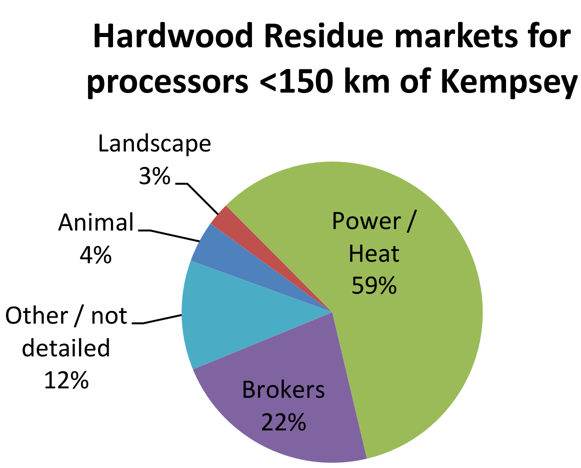
Primary processors spent an average of $233,000 on energy each year, about 4% of turnover, predominantly electricity. Twelve respondents used heat to dry timber; six processors used residues to generate heat; two had co-generation plants, though the electrical component in one was non-operational. Four processors used gas to dry timber.

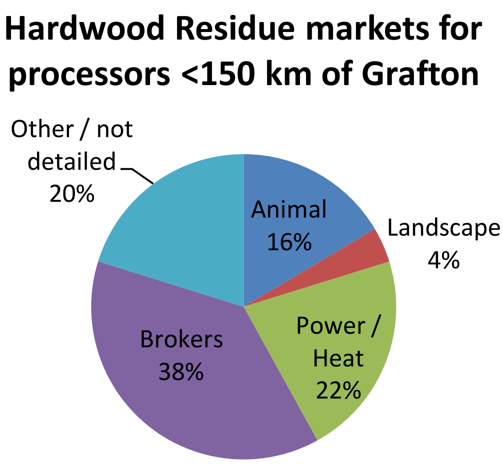
There are options for processors to generate electricity in co-generation plants. However, given a low appetite for investment by processors operating timber drying mills, and the relatively high capital cost and divergent reported capital pay-back times, the four mills using gas are unlikely to switch to co-generation at current prices. They may switch to residue heat dependant on age of current boilers and gas prices.

Respondent's views on residues were generally that unless there are new entrants, the price and demand for residues will remain the same. A number hope for new bioenergy power plant(s) to generate electricity or co-firing of biomass in existing coal fired power stations.

Figure 2.2 Residue markets in each hub.







3. Valuing Residues

Nick Cameron

3.1 Background

The economics of utilising mill and forest residues for bioenergy requires an understanding of their supply and demand. The North Coast Residues Project has identified and quantified eight different categories of woody residue which if combined amount to over 1.3 million tonnes[2] of annually available resource.

Each category of residue has its own distinct characteristics which together determine its value as a bioenergy feedstock. In particular, the location, physical form and moisture content of the residue has a major bearing on its production cost.

Being a low value commodity product, bioenergy feedstock production costs must be kept to a minimum. Price however is not the sole criteria on which a residue resource may be economically evaluated. Scale and reliability of supply are also important economic considerations.

Although of low value (excluding habitat values), residues should not be regarded as waste or have a zero economic value. As revealed in the previous chapter, many mill residues have existing markets. Similarly, forest residues have in the past been commercially utilised as pulpwood. The economic valuing of residues must therefore include a stumpage value that is sufficient to motivate the seller to make the product available.

3.2 Objective and Method

The aim of this study was to estimate the cost of supplying specified quantities of woody residues to nominal bioenergy plants located at Bulahdelah, Kempsey and Grafton.

3.4 Method

The resource as defined in previous chapters occurs within a 150 kilometre radius of the three processing hubs. It should be noted that the 100km and 150km radii overlap so some residues are accounted for twice. This is not an issue when the hubs are considered in isolation. Eight (8) separate categories of residues were costed, four 'in forest' (Table 3.1) and four 'in mills' (Table 3.2). Dry mill residues were excluded. No data was available for private softwood or private hardwood plantations. Private hardwood plantations are a large potential source of bioenergy feedstock, particularly within the Grafton hub.

[2] Includes mill and forest residues within 150km radius of three north coast processing hubs

Table 3.1 – Estimated Hardwood and softwood forest residue quantities available on the NSW North Coast

		Public NF - Green pulpwood logs (tonnes/year)	Private NF - Green pulpwood logs (tonnes/year)	Public Hwd Ptn - Green pulpwood logs & residues chipped (tonnes/year)	Public Swd Ptn - Green pulpwood logs & residues chipped (tonnes/year)
Bulahdelah	<50km	36,497	23,160	7,000	-
	50-100km	88,427	71,574	27,815	-
	100-150km	162,848	101,862	45,655	70,529
Kempsey	<50km	55,607	30,353	6,435	-
	50-100km	150,187	88,547	32,920	218
	100-150km	260,026	159,938	63,000	41,471
Grafton	<50km	64,665	111,552	19,765	17,242
	50-100km	174,855	209,731	79,070	24,117
	100-150km	229,500	264,229	139,956	35,740

Table 3.2 – Estimated Hardwood and softwood processing mill residue quantities available on the NSW North Coast.

		Swd Sawmill - Green offcuts (tonnes/year)	Swd Sawmill - Green sawdust (tonnes/year)	Hwd Sawmill - Green offcuts (tonnes/year)	Hwd Sawmill - Green sawdust (tonnes/year)
Bulahdelah	<50km	-	-	28,219	10,853
	50-100km	-	-	31,729	12,203
	100-150km	-	-	71,201	27,385
Kempsey	<50km	-	-	27,252	10,482
	50-100km	-	-	80,476	30,953
	100-150km	-	-	88,949	34,212
Grafton	<50km	-	-	41,735	16,052
	50-100km	23,945	7,982	46,945	18,056
	100-150km	53,537	17,846	107,085	41,187

The assumed wood properties of the eight residues categories are detailed in Table 3.3 and Table 3.4 for forest and mill categories respectively.

The value of each residue category was separately estimated using a purpose built model, the 'Residue Valuation Model'. The value of each category was then multiplied by the relevant resource quantity to obtain a weighted average residue value for each zone within each hub.

The components of the Residue Valuation Model that were used to calculate the value of each residue category are detailed in Table 3.5.The components include allowances for harvesting, transport, chipping, stumpage and calorific values. Allowances for loading and unloading were incorporated into the chipping and transport costs. No allowance was made for storage.

Forest residue transport distances were calculated in ArcGIS Pro using Network Analysis Tools - Original Distance Cost Matrix (Type: Trucking – Forestry Corporation of NSW road layer). The results of the transport analysis for public native forest and for private native forest are detailed in Figure 3.1 and Figure 3.2 respectively.

Table 3.3- Assumed wood properties of hardwood and softwood forest residues

	Public NF - Green pulpwood logs	Private NF - Green pulpwood logs	Public Hwd Ptn - Green pulpwood logs & residues chipped	Public Swd Ptn - Green pulpwood logs & residues chipped
Oven dry mass density (t/m3)	0.71	0.71	0.58	0.55
Green density (t/m3)	1.15	1.15	1.02	1.10
Oven-dry calorific value (Gigajoules/tonne)	18.76	18.76	18.76	20.20
Moisture content on wet basis (5)	38	38	42	44
Net calorific value (gigajoules/tonne)	10.7	10.7	9.9	11.3

Table 3.4 – Assumed wood properties of hardwood and softwood mill residues

	Swd Sawmill - Green offcuts	Swd Sawmill - Green sawdust	Hwd Sawmill - Green offcuts	Hwd Sawmill - Green sawdust
Oven dry mass density (t/m3)	0.55	0.55	0.71	0.71
Green density (t/m3)	1.10	1.10	1.15	1.15
Oven- dry calorific value (Gigajoules/tonne)	20.2	20.2	18.6	18.6
Moisture content on wet basis (5)	46	44	38	36
Net calorific value (gigajoules/tonne)	10.9	11.3	10.7	11.1

Table 3.5 – Costing components of the Residue Valuation Model

	Type	Model input	Units
I.	Harvesting	Single native forest pulpwood harvesting rate based on integrated sawlog harvesting operations	$/green tonne
II.		Single rate for thinning and clearfall harvest of hardwood plantations for pulpwood and residues	$/green tonne
III.		Single rate for thinning and clearfall harvest of softwood plantations for pulpwood and residues	$/green tonne
IV.	Haulage	Average distance to haul public native forest pulpwood from State forest compartments to bioenergy plant by hub and zone (Figure 3.1)	kilometres
V.		Average distance to haul private native forest pulpwood from properties with an approved PNF PVP to bioenergy plant by hub and zone (Figure 3.2)	kilometres
VI.		Average distance to haul public hardwood plantation pulpwood & residues to bioenergy plant by hub and zone	kilometres
VII.		Average distance to haul public softwood plantation pulpwood & residues to bioenergy plant by hub and zone	kilometres
VIII.		Average distance to haul mill residues from mills to bioenergy plant by hub and zone	kilometres
IX.		Single haulage rate schedule for haulage of native forest pulpwood, chipped plantation pulpwood & residues and chipped mill residues	$/km/green tonne
X.	Chipping	Rate for infield chipping of plantation pulpwood and residues	$/green tonne
XI.		Rate for chipping native forest pulpwood at designated processing site	$/green tonne
XII.		Rate for chipping mill offcuts at mill	$/green tonne
XIII.	Stumpage	Rate for public and private native forest pulpwood by hub and zone	$/green tonne
XIV.		Rate for public hardwood plantation pulpwood & residues by hub and zone	$/green tonne
XV.		Rate for public softwood plantation pulpwood & residues by hub and zone	$/green tonne
XVI.		Rate for hardwood mill residues by category	$/ green tonne
XVII.		Rate for softwood mill residues by category	$/ green tonne
XVIII.	Calorific value	Value by residue category	Gigajoules/tonne

Figure 3.1 – Average distances by road between State forest compartments and hubs (Buladelah, Kempsey and Grafton) and zones (0-50km radius, >50-100km radius and >100-150km radius). Calculated using ArcGIS Pro Network Analysis Tools

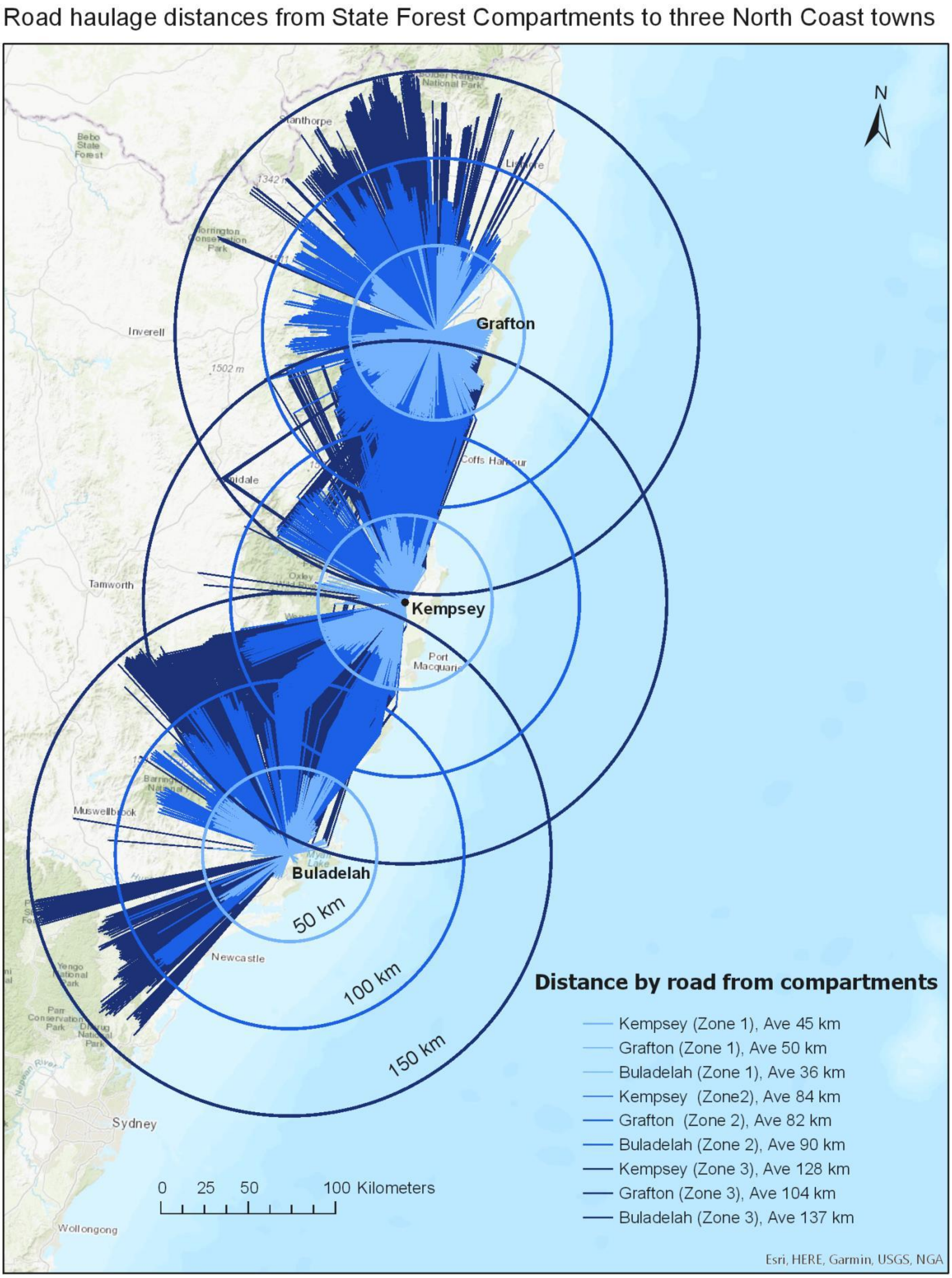
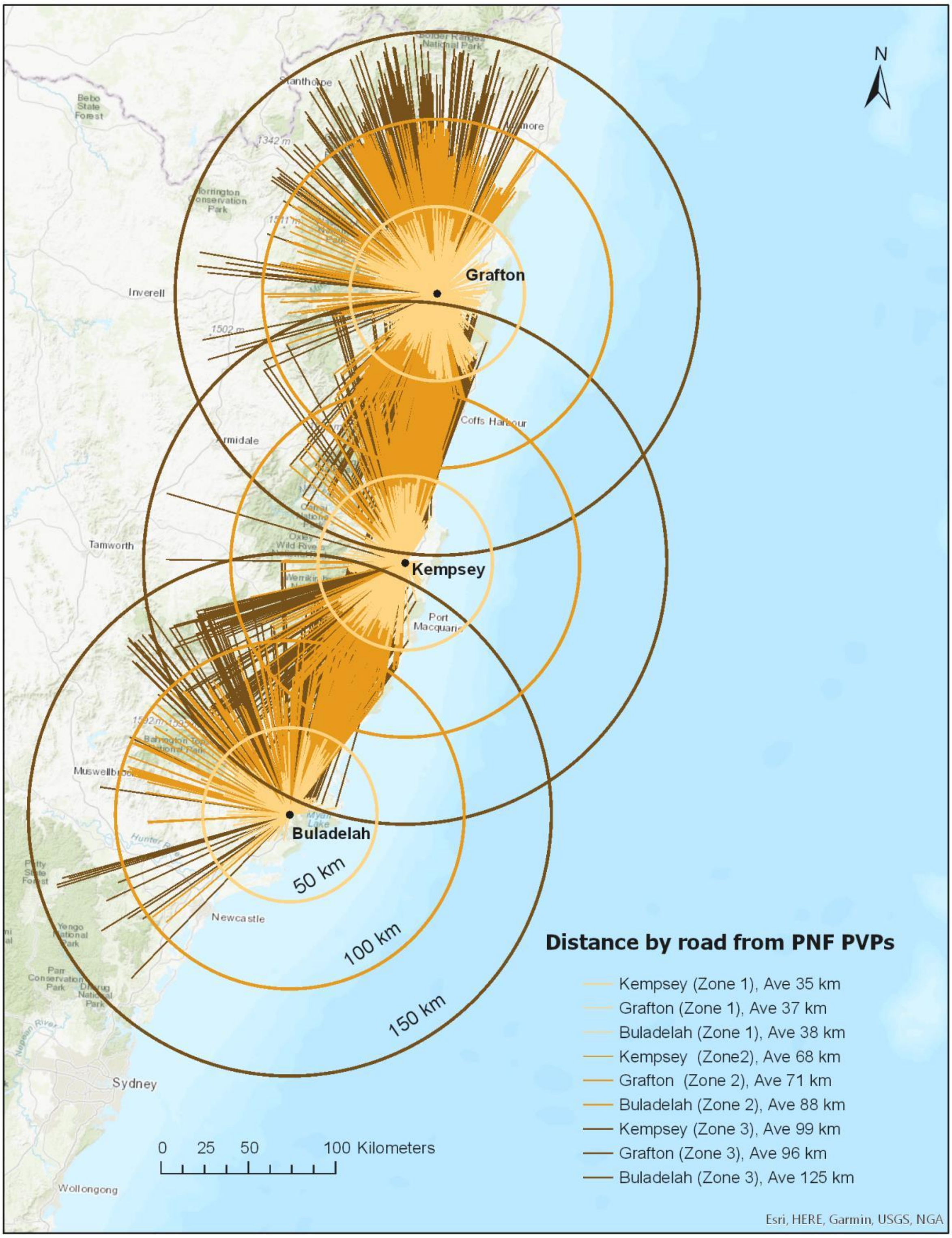


Figure 3.2 - Average distances by road between private properties with an existing PNF PVP and hubs (Buladelah, Kempsey and Grafton) and zones (0-50km radius, >50-100km radius and >100-150km radius). Calculated using ArcGIS Pro Network Analysis Tools

Road haulage distances from properties with approved PNF PVPs to three North Coast towns



3.5 Results

The quantity of available residue in tonnes and gigajoules and their weighted average delivered price by zone[3] for each of the three hubs is detailed in Table 3.6.

Table 3.6 – Annual quantity of residues and weighted average delivered price of residues by hub and zone[4]

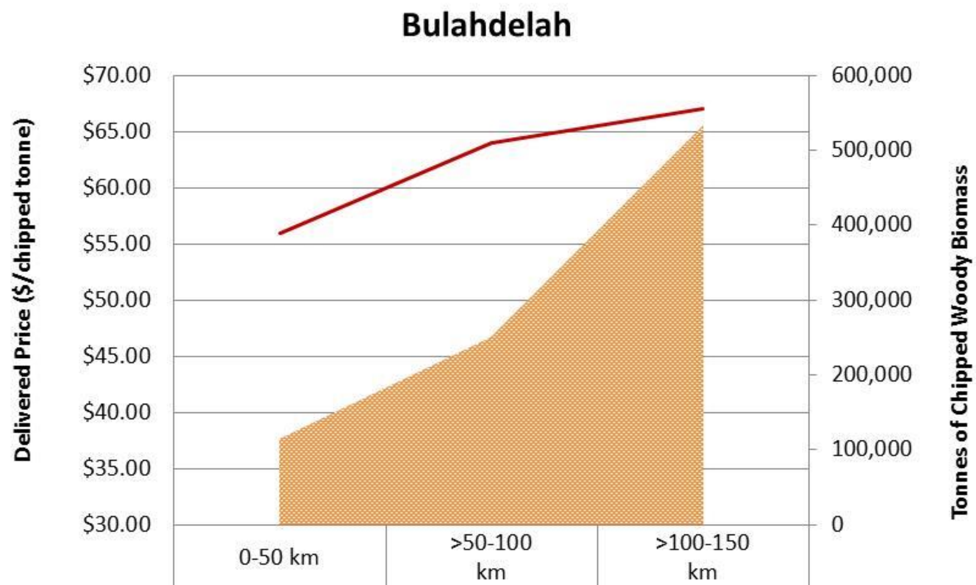
		Residue Quantity (tonnes of chip)	Residue Quantity (GJ)	Residue Cost ($)	Wt Ave Delivered Price ($/tonne of chip)	Wt Ave Delivered Price ($/GJ)
Bulahdelah	0-50 km	105,747	1,130,569	$5,940,003	$56.00	$5.86
	>50-100 km	124,022	1,312,143	$7,940,821	$64.00	$6.56
	>100-150 km	236,063	2,564,444	$15,770,073	$67.00	$7.47
Kempsey	0-50 km	104,713	1,119,836	$5,038,245	$48.00	$4.81
	>50-100 km	278,631	2,968,842	$15,852,958	$57.00	$5.79
	>100-150 km	263,242	2,818,055	$17,030,470	$65.00	$6.96
Grafton	0-50 km	258,729	2,764,679	$14,173,206	$55.00	$5.62
	>50-100 km	327,499	3,476,144	$19,844,590	$61.00	$6.63
	>100-150 km	272,794	2,890,019	$16,506,575	$61.00	$7.20

The results for individual hubs are presented in graphical form in Figure 3.3 (Bulahdelah), Figure 3.4 (Kempsey) and Figure 3.5 (Grafton). In these graphs the quantities are cumulative while the delivered price is discrete to the particular zone. Weighted average prices range from $48/ tonne of chip to $67/tonne of chip. If chipped mill residues are excluded the weighted average delivered price increases, ranging between $58 and $70/tonne of chip.

[3] Delivered price includes undisclosed stumpages

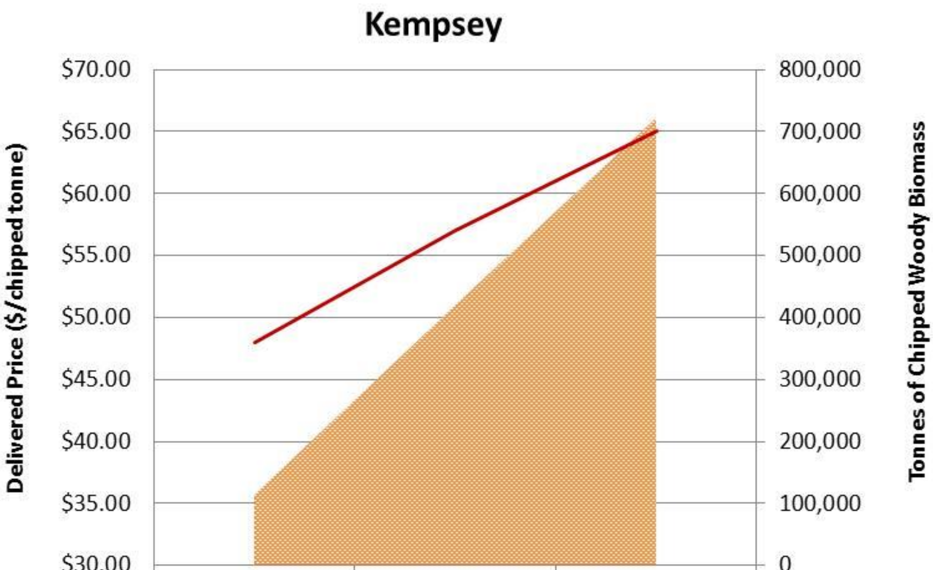
[4] Quantities are discrete for each zone

Figure 3.3 – Quantity of residues and weighted average delivered price of residues by zone for Bulahdelah



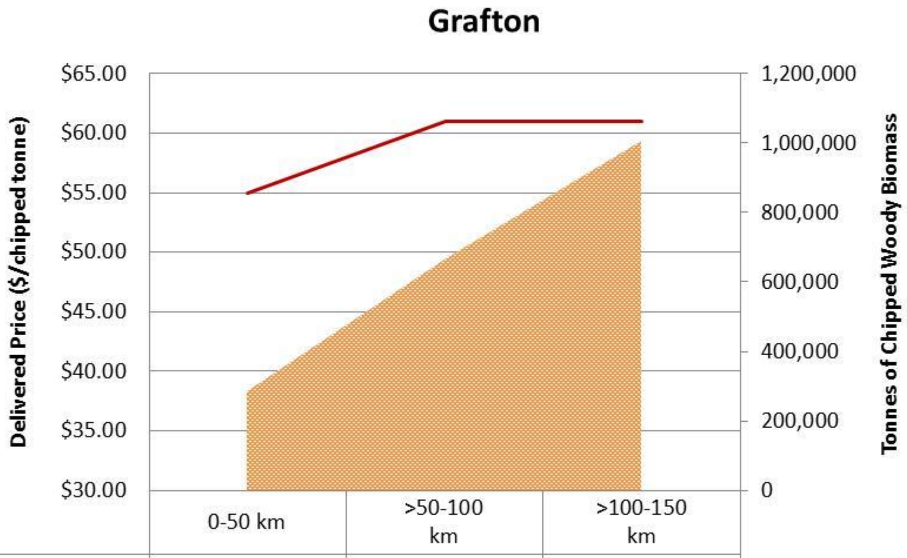
	0-50 km	>50-100 km	>100-150 km
Quantity (tonnes of chip)	114,967	249,787	532,445
Wt Ave Delivered Price ($/tonne of chip)	$56.00	$64.00	$67.00

Figure 3.4 - Quantity of residues and weighted average delivered price of residues by zone for Kempsey



	0-50 km	>50-100 km	>100-150 km
Quantity (tonnes of chip)	113,220	418,093	721,357
Wt Ave Delivered Price ($/tonne of chip)	$48.00	$57.00	$65.00

Figure 3.5 – Cumulative quantity of residues by Zone and weighted average delivered price of residues by Zone for Kempsey



	0-50 km	>50-100 km	>100-150 km
Quantity (tonnes of chip)	284,775	665,993	1,006,853
Wt Ave Delivered Price ($/tonne of chip)	$55.00	$61.00	$61.00

3.6 Discussion

The outputs of the Residue Valuation Model provide prospective buyers with indicative 2017 prices for specified quantities of delivered chip to three discrete processing hubs. If the location of the processing hub were to change this would change both the quantity of available residue and the associated costs to produce and deliver it.

All delivered prices generated by the Residue Valuation Model incorporate a stumpage (or royalty). Stumpage prices must be negotiated with individual suppliers. The undisclosed stumpages in the model are the prices that we estimate may be sufficient to incentivise a supplier to make their residue material available. In reality the actual stumpage price will vary between sellers and be influenced by market conditions at the time.

Production costs for forest residues were notably higher than the production costs for mill residues. Within the forest residue category the production costs for plantation residues were lower than for native forest residues however a stumpage price differential resulted in delivered prices that were comparable.

Production costs for private native forest residues were marginally cheaper than for public native forests due to their relative proximity to the processing hubs. Public native forests however had the greatest quantities of residue (pulpwood), and are available from a single supplier. In contrast, the estimated quantities of residue available from private native forests come from several thousand individual suppliers.

The outputs of the Residue Valuation Model will be further refined as new resource data comes to hand and as more accurate production cost information become available.

4. Chemical composition and extractive compounds from key native hardwood species from the NSW North Coast.

Shane Mcintosh, Fabiano Ximenes

4.1 Background

There is growing interest worldwide in the potential for bio-chemical production from tree biomass. Within Australia, there has been limited research into the bio-chemical potential of native commercial species and how harvest and processing residues may be utilised for this application. Most of the existing knowledge is based on old-growth stock or more recently on young plantation material – however the public native hardwood estate in NSW is classified as regrowth forests, with typical harvest cycles of 50-60 years.

The key aims of this investigation were to: 1) determine the calorific value of key hardwood species; 2) determine the chemical composition of major components in hardwood biomass fractions; 3) identify any major areas of variability that might attribute superior downstream applications; 4) identify any unique compounds enriched in heartwood samples and more broadly determine if heartwood biomass is an exploitable resource for recovery of chemicals. A preliminary investigation into anti-corrosion potential of eucalyptus extracts was also conducted.

4.2 Methods Summary

Samples from key species were prepared from samples in the regrowth native hardwood forests included in Chapter 1. Samples of bark, branches and wood at various positions along the stem profile were assessed for major chemical component composition. Further chemical profiling of both polar and non-polar extractive fractions was performed. The samples were chosen based on observed differences in calorific values.

Sugars and organic acids were determined using high-pressure liquid chromatography (HPLC). Chemical extractions were carried out using a Methanol:chloroform:water extraction solvent.

In addition to the woody components, fresh green blackbutt bark and sapwood samples were subjected to the same extraction procedure and were included in the analysis. Hot water extraction was carried out for the bark component, with a preliminary analysis of the potential anti-corrosion properties of extractives.

4.3 Results and Discussion

4.3.1 Calorific Value and Composition analysis

The calorific value (dry wood basis) for the wood species tested here did not vary much and ranged from 18.6-19.3 MJ/kg (Table 4.1). These values are in line with typical values reported in the literature for hardwoods.

Total methanol extractive fractions varied considerable between wood samples and ranged from 3% to 18% (Table 4.2). Tallowwood had substantially higher level of lipophilic extractives (~18%) than any other species tested. Water extractive fractions did not vary much, ranging between 3-5% (Table 4.2).

Table 4.1 Calorific value of key native forest hardwood species on the NSW North Coast

Wood	N	CV (MJ/kg; mean, SD)
Blackbutt	24	18.6 (0.5)
Flooded gum	6	18.7 (0.3)
Blue gum	5	18.9 (0.35)
Tallowwood	3	19.1 (0.15)
Ironbark	3	19.2 (0.2)
Red mahogany	3	19.3 (0.05)

The lignin and holocellulose content of the different wood species ranged between approximately 24 to 30%, and 43-47% (Table 4.2) respectively (extractive-free basis). Looking at the chemical composition from a bioenergy potential, if biofuel (liquid fuels) is of interest, then species with higher holocellulose (carbohydrates) are preferred. Tallowwood would be considered a less desirable species for that purpose, as its higher extractive content corresponded to a lower carbohydrate concentration compared to other species (Table 4.2). In contrast the higher proportion of extractives and lignin present in tallowwood is conducive to higher calorific values, and hence for an application in combined heat and power applications.

Table 4.2 Chemical compositional analysis of heartwood from key native forest species on the NSW North Coast (dry wood basis)

Species	Position	Methanol extractives	Water extractives	Lignin	Holocellulose
		%	%	%	%
Blackbutt	Branch	4.45	3.67	22.66	43.8
Blackbutt	Branch	6.6	4.12	24.55	41.17
Blackbutt	Wood-middle	4.25	5.17	22.04	46.75
Blackbutt	Wood - lower	9.85	3.88	26.31	39.32
Blackbutt	Wood - lower	7.3	3.13	25.98	41.4
Blackbutt	Wood-middle	8.75	3.78	23.47	42.16
Tallowwood	Wood - lower	18.75	4.55	21.86	33.63
Tallowwood	Wood - upper	13.15	4.78	23.66	36.75
Flooded Gum	Wood - lower	9	2.95	26.71	40.18
Flooded Gum	Wood - upper	3.1	3.1	25.01	43.69

4.3.2 Native hardwood chemical profiling

A summary of the three most common compounds identified from eucalyptus wood and bark samples is presented in Table 4.3. A total of 75 compounds were separated including sugars, carboxylic/benzoic acids, phenolic acids and glycerol.

Chemical compounds in polar extractives

The bark material was, as expected, generally more enriched in the majority of compounds compared to the woody material. Tallow wood was generally more enriched in polar extracts compared to both blackbutt and flooded gum, in agreement with extractive levels reported previously. Tallowood also contained the highest level of gallic acid (Table 4.3), which is a phenolic acid and considered a versatile and powerful antioxidant with promising therapeutic and industrial applications. Gallic acid is reported to have anti-fungal and anti-viral properties and has been found to show cytotoxicity against cancer cells. An historical application is in the making of inks and dyes. A mature tallowwood tree will contain approximately 10 kg of gallic acid (from a concentration of 1.84 kg /tonne dry matter); potentially available residues would contain between 2-3kg of this compound.

Flooded gum contained the highest level of Catechin (Table 4.3), a type of natural phenol and antioxidant found mainly in tea and cocoa, belonging to the chemical family of flavonoids. The European Food Safety Authority established that related flavanols (from cocoa) have a positive effect on vascular function in healthy adults. A meta-analysis also indicated that catechins may favourably affect cholesterol. A mature flooded gum tree will contain approximately 12 kg of catechin (from a concentration of 3.4 kg /tonne dry matter); potentially available residues would contain between 2.5-3.5kg of this compound.

Table 4.3 Relative abundance of key compounds of interest present in the extractives in bark and wood fractions

Key compounds	Blackbutt			Tallowwood	Flooded gum
	Bark (%)	Sapwood (%)	Wood (%)	Wood (%)	Wood (%)
Gallic acid	1.1	1.5	5.1	15.3	7.5
Catechin	2.24	0.51	0.11	0.0	9.5
Lactic acid	2.91	0.54	0.06	0.35	0.15

Eucalyptus extracts as a ‘green’ corrosion inhibitor

There is growing interest in the replacement of environmentally hazardous chromates with natural plant products as inexpensive eco-friendly corrosion inhibitors. Extracts from plant material have been reported to function as effective inhibitors of metal and alloy corrosion. They are adsorbed onto the metal surface through the polar atoms, forming protective films. Many different plant extracts have been explored and tested on various alloys, including from Eucalyptus species [5].

We conducted some preliminary experiments to test hot water extracts from blackbutt bark as a corrosion inhibitor of steel in extreme acidic environments. In the first experiment, we immersed the swarf in solutions of concentrated sulfuric acid with varying amounts of hot water extracts (Table 4.4). The swarf immersed in the acid concentration mixed with 50% bark extracts had weight losses of 8-10%, compared to 26-45% loss for the material immersed in sulfuric acid alone. The steel was blackened for samples immersed in the solution containing bark extracts, whereas the steel in the sulfuric acid alone was visibly corroded. This suggests organic compounds in the extracts (and crude sap) adsorb to the substrate surface providing a protective barrier. It was also observed that when steel was exposed to crude sap, the adsorption was virtually immediate and more intense than a hot water extract. This is not surprising as the water extracts contain only a fraction of the compounds as compared to the sapwood.

Further work is required to provide definitive and quantitative effectiveness of native hardwood extracts as corrosion inhibitors. Different alloys should also be investigated, as literature indicates little is known on what the active compounds might be.

Table 4.4 Anti-corrosion study by weight loss in acidic environment.

test	solution	extract	iron swarf start	iron swarf final (@24h)	solid loss
		%v/v	g	g	%
1a	1M H2SO4	0.0	0.351	0.192	45.36
1b	1M H2SO4	1.0	0.304	0.177	41.98
1c	1M H2SO4	50	0.314	0.288	8.22
2a	1M H2SO4	0	0.510	0.377	26.00
2b	1M H2SO4	10	0.459	0.317	30.93
2c	1M H2SO4	50	0.574	0.515	10.29

[3] A few references are relevant here. Green corrosion inhibitors-An Overview' – mentioned eucalyptus extracts from leaves as effective on mild steel. Reference- A.Minhaj,P.A.Saini,M.A.Quraishi, I.H. Farooqi,"A study of natural compounds as corrosion inhibitors for industrial cooling systems". Corrosion Prevention and Control 46(2), (1999), pp.32-38.);

Eucalyptus oil –anodic inhibitor of 2507 steel in H2S)4/ HCL. Reference (J.H.Potgieler, P.Olubambi, N.P.Thanjekwayo, "The effect of selected plant extracts on the corrosion behaviour of duplex stainless steels". EUROCORR 2008-European Corrosion Congress: Managing Corrosion for Sustainability, Book of Abstracts, (2008), pp.78-79.);

Article title- 'Green Corrosion Inhibitor from Essential Oil of Eucalyptus globulus (Myrtaceae) for C38 Steel in Sulfuric Acid Solution'. Study showed essential oil extract was an effective corrosion inhibitor of C38 steel in 0.5M H2SO4 . essential oil behaves as a mixed-type inhibitor in sulfuric acid.

5. Extraction of biomass for bioenergy from NSW North Coast regrowth native forests: impacts on nutrient availability

Fabiano Ximenes, Kate Wright, Michael Mclean, Rebecca Coburn

5.1 Background

The extraction of biomass in addition to sawlogs and other high value log products may have implications for the future nutritional needs of the forest. When a forest is harvested, nutrients may be lost in harvested wood, bark and other tree components, and there are further losses by volatilization and particulate convection during regeneration burning, and by erosion and leaching[6]. The impacts will be different for native systems compared to plantations. Because of shorter rotation times, harvest of timber is more likely to lead to a decline in productivity in plantations than in native forests, despite the application of fertilisers[2]. The higher intensity of the harvest (i.e. clearfell), and also previous land use impact on nutrient levels for plantations.

In this section we focus on native forests, as that is typically the focus of concerns raised when extraction of biomass for bioenergy is considered. It is widely accepted that the longer native forest rotations (compared to plantations) are usually sufficient to ensure replenishment of nutrients by rainfall, biological fixation and weathering[4]. Furthermore, rapid regrowth, recovery of microbial activity and other processes are considered to limit nutrient losses in native systems[7,8]. However, most of the existing available literature on the nutrient composition of different biomass fractions in native forests is somewhat dated and relates primarily to old-growth stands, whereas the current resource in NSW is regrowth forests, typically ranging from 50-60 years old at the time of harvest.

In this section we present the nutrition composition for key native hardwood species in regrowth stands in the NSW North Coast, for each of the three study hubs. The nutrition data is provided for key biomass fractions (stem wood, branches, bark, leaves and litter). The total mass for key nutrients is given for each biomass fraction. This approach allows the determination of the proportion of nutrients that may be removed as a result of the extraction of biomass for bioenergy, and provides a useful snaphot of the impact of extraction on the nutrient profile immediately post-harvest. However, this study does not constitute a full nutrient budget that would also take into account temporal and below-ground conversion dynamics, and natural nutrient inputs (e.g. via rainfall).

5.2 Methods Summary

A total of 312 biomass samples of stem wood, branches (small and large), leaf, bark and litter were collected from various harvest sites spanning the range of forests available in each of the study hubs. The biomass was ground to (0.5-1.0 mm) and analysed for total N and C by the Dumas combustion method and acid extractable elements and metals by ICP (Inductively Coupled Plasma spectrometry). Initially the biomass fractions were divided according to position in the tree and diameter size, in order to determine the level of variability, if any, in the nutrient content. Where no significant differences were found, the nutrient determinations were combined

[6] Judd, T.S. 1996. Simulated nutrient losses due to timber harvesting in highly productive Eucalypt forests and plantations. In: Attiwill, P.M. and Adams, M.A (Eds.): Nutrition of Eucalypts. CSIRO.

[7] Polglase, P. et al. 1986. Immobilization of soil nitrogen following wildfire in two eucalypt forests of south-eastern Australia. Oecologia Plantarum. 7, 261-271

[8] Attiwill, P.M. 1994. Ecological disturbance and the conservative management of eucalypt forests in Australia. Forest Ecology and Management. 63: 301-346.

for a given biomass component. In this section we report on a subsection of elements typically considered most important (N,P,K, S, Ca, Mg).

The proportion of biomass in the various tree components was calculated to determine the impact of removal of the biomass for bioenergy or other applications on total above-ground nutrient levels at the time of harvest. Business as usual (BAU) was defined here as leaving all residues (including pulp logs) in the forest to burn or decay over time. The biomass proportions used were based on previous biomass studies involving key species in the different hubs[9,10,11]. In order to calculate nutrient losses due to BAU harvest and the additional harvest of biomass for bioenergy, we firstly calculated the proportion of biomass in each of the key fractions, including litter. These factors were applied to the total estimated volume of pulpwood (used for bioenergy) for key species in each hub to determine the relative biomass contribution of each species. For example, for Bulahdelah blackbutt accounted for 63% of the biomass, followed by tallowwood with 18% of the total. We then determined the weighted average of nutrients in each biomass fraction, based on the relative contribution of each species to the total biomass in each hub. These values were then used to calculate nutrient removal due to harvest.

5.3 Results and Discussion

5.3.1 Concentration of major nutrients in key biomass fractions

In Figure 5.1- Figure 5.6 the relative concentrations of the various nutrients in bark, branch, leaf and wood fractions are presented. The nutrient concentrations of litter samples were included in Section 5.3.4). The litter layer is considered relatively nutrient-rich (except for potassium), and it typically accounts for between 5-6% of the above-ground biomass[5,7].

Overall, the nutrient concentrations were within ranges reported for native forest systems in SE Australia[12]. Also consistent with the available literature, the nutrient concentration in leaves was higher than for other fractions for all nutrients with the exception of calcium, which is more concentrated in the bark (Figure 5.6). The nutrient concentration of the stem wood (which represents the majority of the biomass in mature native forests) was invariably lower than for other biomass fractions. As leaves and bark are left in the forest following harvest of native forests, a large proportion of nutrients are left on-site.

[9]Ximenes, F.; Gardner, W.D.; Marchant, J.F. Carbon Flow Following the Harvest of Blackbutt Trees and Their Conversion into Sawn Products; Research Paper No. 41; NSW Department of Primary Industries: Sydney, Australia, 2005

[10]Ximenes, F.et al. 2014. Determining coarse woody debris and fine litter in native forests in New South Wales and Victoria. A report for the Federal Dept. of Environment

[11]Ximenes, F et al 2016. Carbon stocks and flows in native forests and harvested wood products in SE Australia. Report prepared for Forests and Wood Products Australia (FWPA), January 2016. http://www.fwpa.com.au/images/resources/Amended_Final_report_C_native_forests_PNC285-1112.pdf

[12]Attiwill, P. M. et al. 1996. Nutrient cycling in forests of south-eastern Australia. In: Attiwill, P.M. and Adams, M.A (Eds.): Nutrition of Eucalypts. CSIRO.

Figure 5.1 Mean nitrogen concentration in key biomass fractions for each hub

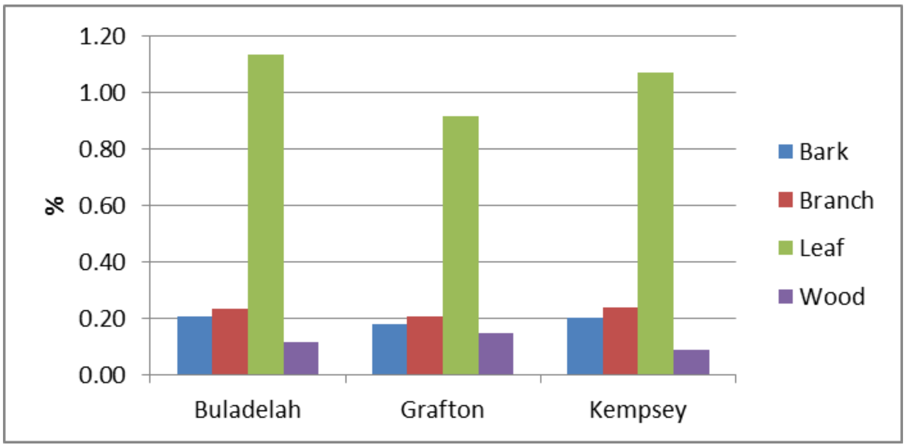


Figure 5.2 Mean phosphorus concentration in key biomass fractions for each hub

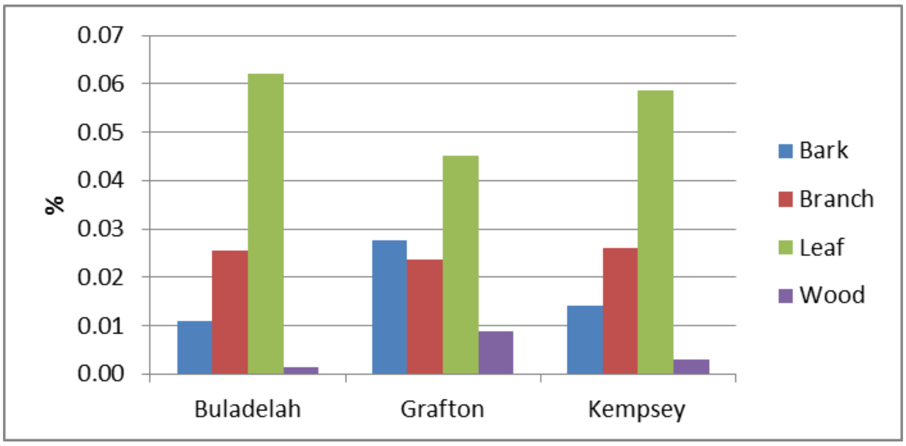


Figure 5.3 Mean potassium concentration in key biomass fractions for each hub

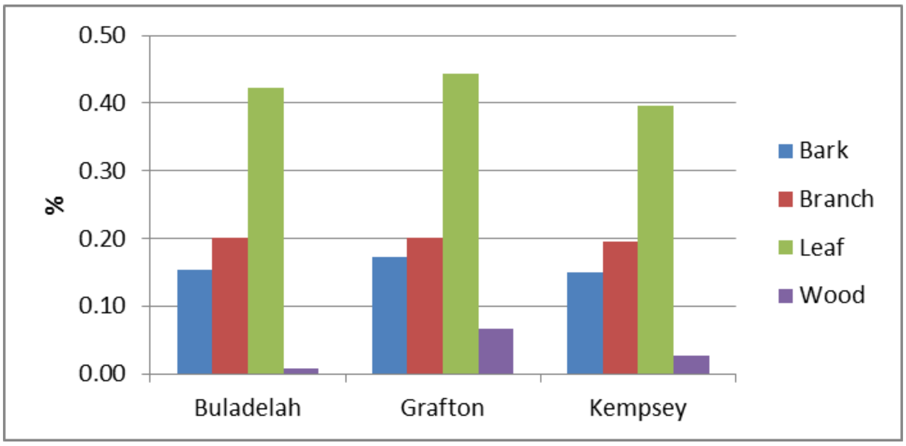


Figure 5.4 Mean magnesium concentration in key biomass fractions for each hub

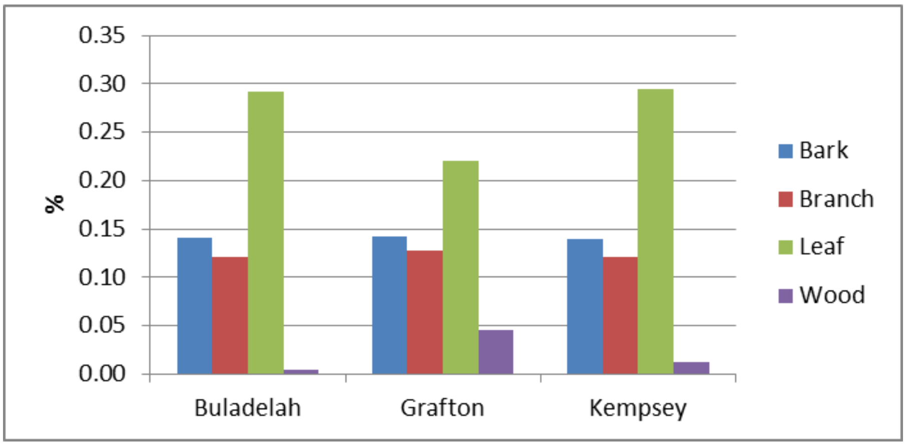


Figure 5.5 Mean calcium concentration in key biomass fractions for each hub

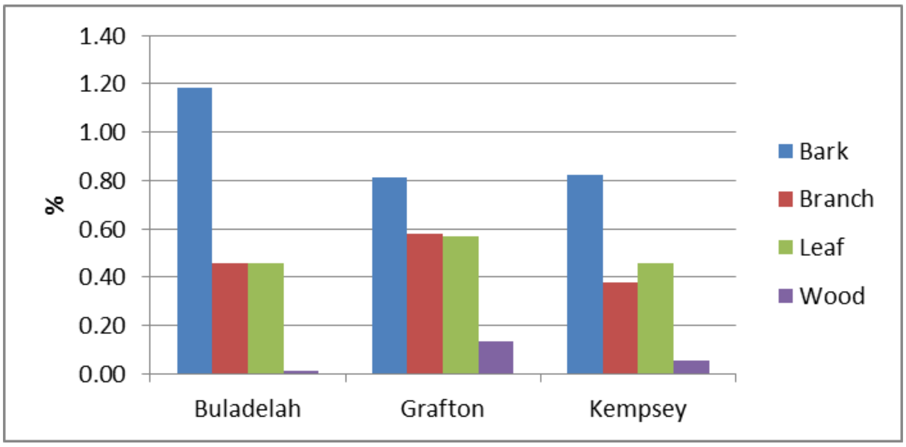
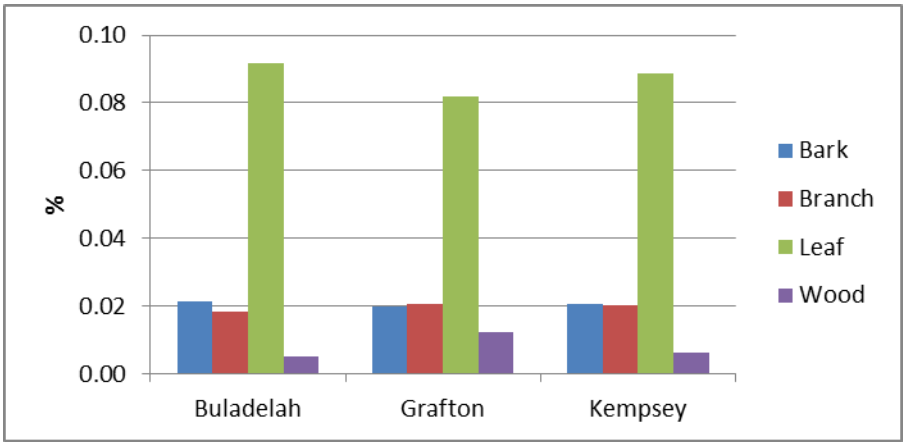


Figure 5.6 Mean sulfur concentration in key biomass fractions for each hub



5.3.2 Concentration of major nutrients in blackbutt – site impact

In Figure 5.7 – Figure 5.12 we present the concentration of key nutrients for blackbutt, the most important commercial species in the regions, for biomass samples from four different forest types dominated by blackbutt in varying geographical locations (within 100 km radius from Kempsey). Blackbutt accounted for 32-50% of the tree above-ground biomass in the study hubs.

Site did not seem to have a significant impact on concentration levels for most nutrients in blackbutt with the exception of some variation in phosphorus levels for bark and branches from Tambam SF (Figure 5.8) and calcium in bark from Comboyne SF (Figure 5.11). Although the Comboyne site was highly productive, especially compared to the Bulls Ground and Tamban sites, that was generally not reflected in higher mean nutrient concentrations of the key biomass fractions, which were largely comparable across sites (Figure 5.7-5.12)

Figure 5.7 Mean nitrogen concentration for blackbutt biomass samples across four study sites

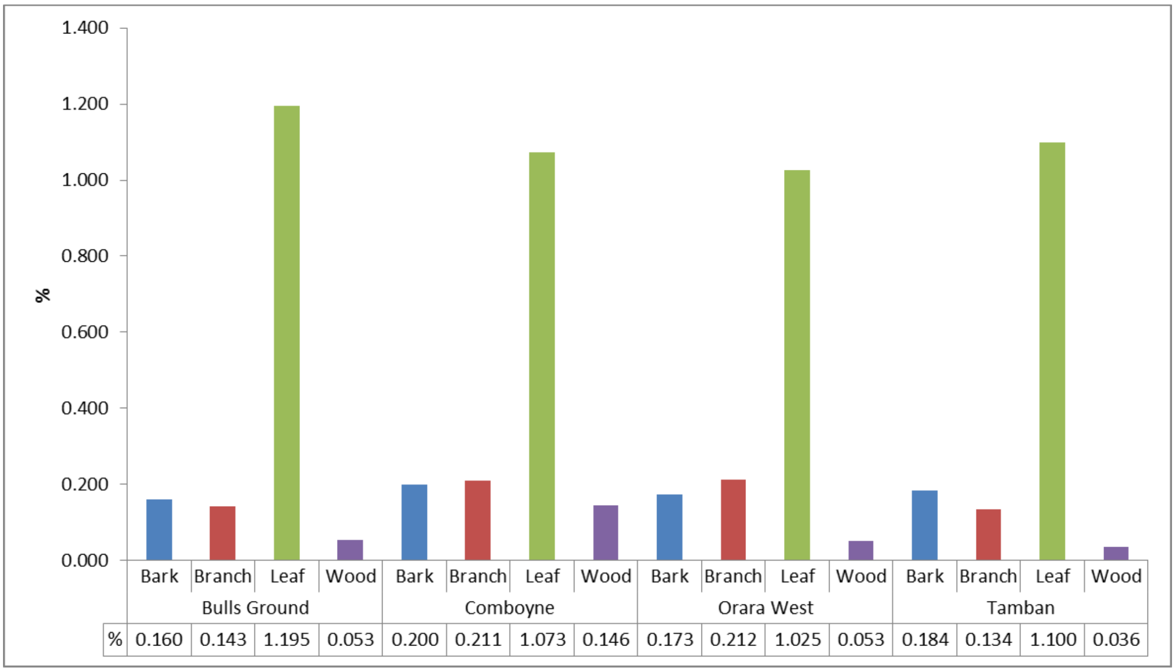
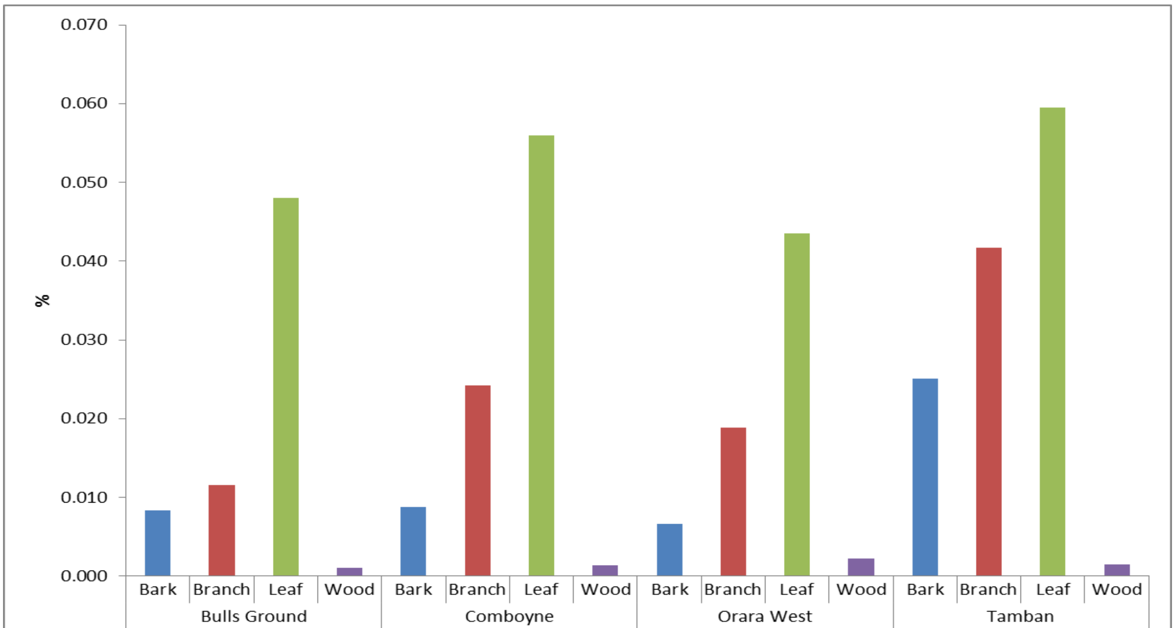
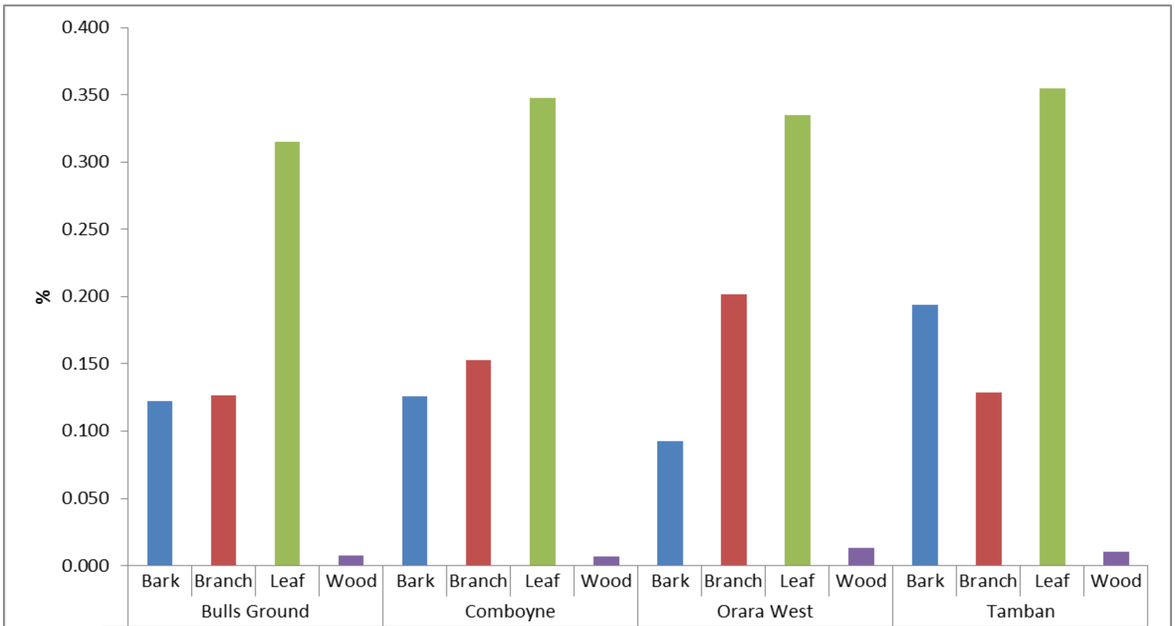


Figure 5.8 Mean phosphorus concentration for blackbutt biomass samples across four study sites



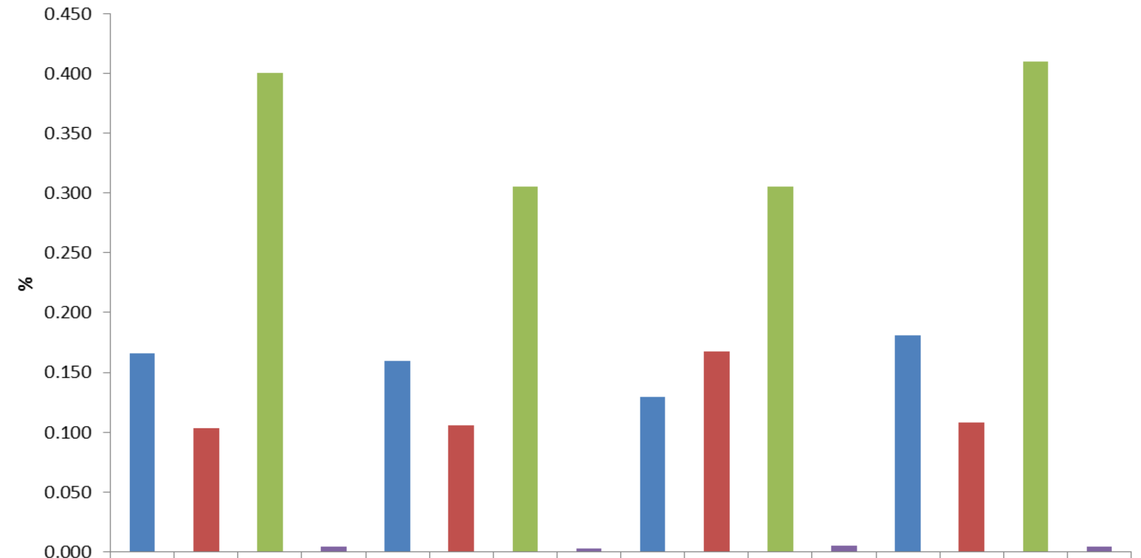
	Bulls Ground				Comboyne				Orara West				Tamban			
	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood
%	0.008	0.012	0.048	0.001	0.009	0.024	0.056	0.001	0.007	0.019	0.044	0.002	0.025	0.042	0.060	0.002

Figure 5.9 Mean potassium concentration for blackbutt biomass samples across four study sites



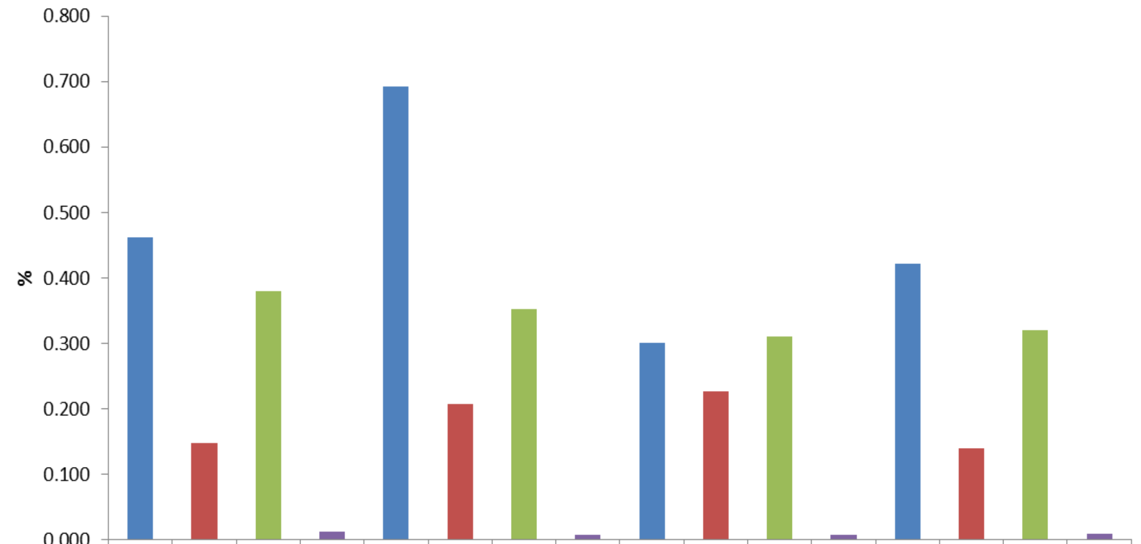
	Bulls Ground				Comboyne				Orara West				Tamban			
	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood
%	0.123	0.127	0.315	0.007	0.126	0.153	0.348	0.007	0.092	0.202	0.335	0.013	0.194	0.129	0.355	0.010

Figure 5.10 Mean magnesium concentration for blackbutt biomass samples across four study sites



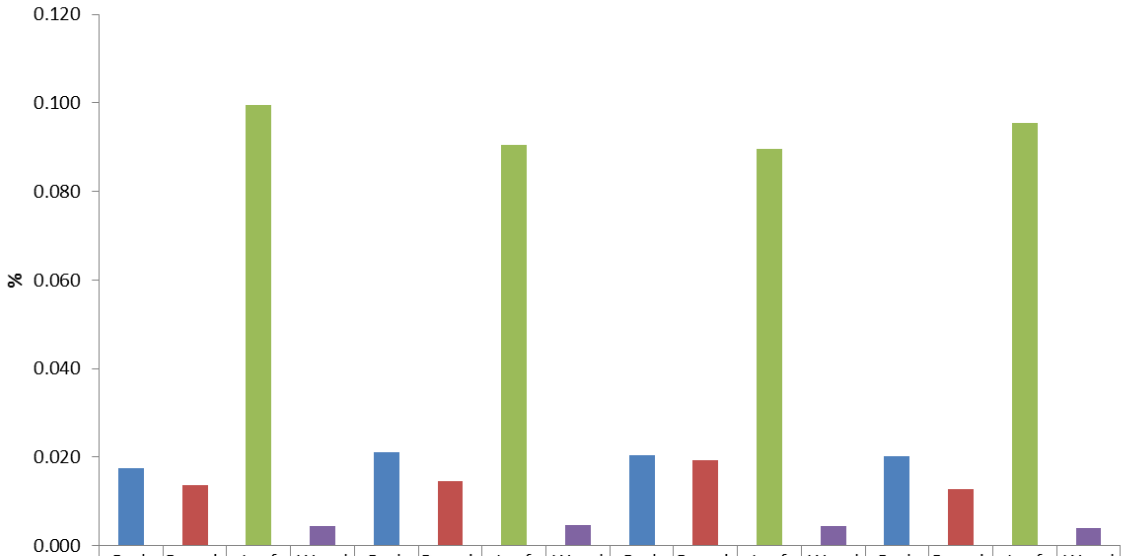
	Bulls Ground				Comboyne				Orara West				Tamban			
	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood
%	0.166	0.103	0.400	0.004	0.159	0.105	0.305	0.003	0.130	0.168	0.305	0.005	0.181	0.108	0.410	0.004

Figure 5.11 Mean calcium concentration for blackbutt biomass samples across four study sites



	Bulls Ground				Comboyne				Orara West				Tamban			
	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood
%	0.463	0.148	0.380	0.012	0.693	0.207	0.353	0.007	0.300	0.227	0.310	0.007	0.422	0.140	0.320	0.009

Figure 5.12 Mean sulfur concentration for blackbutt biomass samples across four study sites



	Bulls Ground				Comboyne				Orara West				Tamban			
	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood	Bark	Branch	Leaf	Wood
%	0.018	0.014	0.100	0.005	0.021	0.014	0.091	0.005	0.020	0.019	0.090	0.004	0.020	0.013	0.096	0.004

5.3.3 Nutrient concentration of biomass fractions within hubs

In Figures 5.13 - 5.16 the nutrient concentration of the various biomass fractions within each of the hubs is presented. The nutrient concentration of the bark and leaves did not differ much between hubs (Figures 5.13 & 5.14). Calcium was the main nutrient in the bark for all study sites (Figure 5.13), confirming what has already been described in the literature. Although the concentration of most nutrients is high in leaves, they are especially nitrogen-rich (Figure 5.14). Phosphorus is low in all biomass fractions, with the highest concentrations in leaves (Figure 5.14).

Figure 5.13 Bark

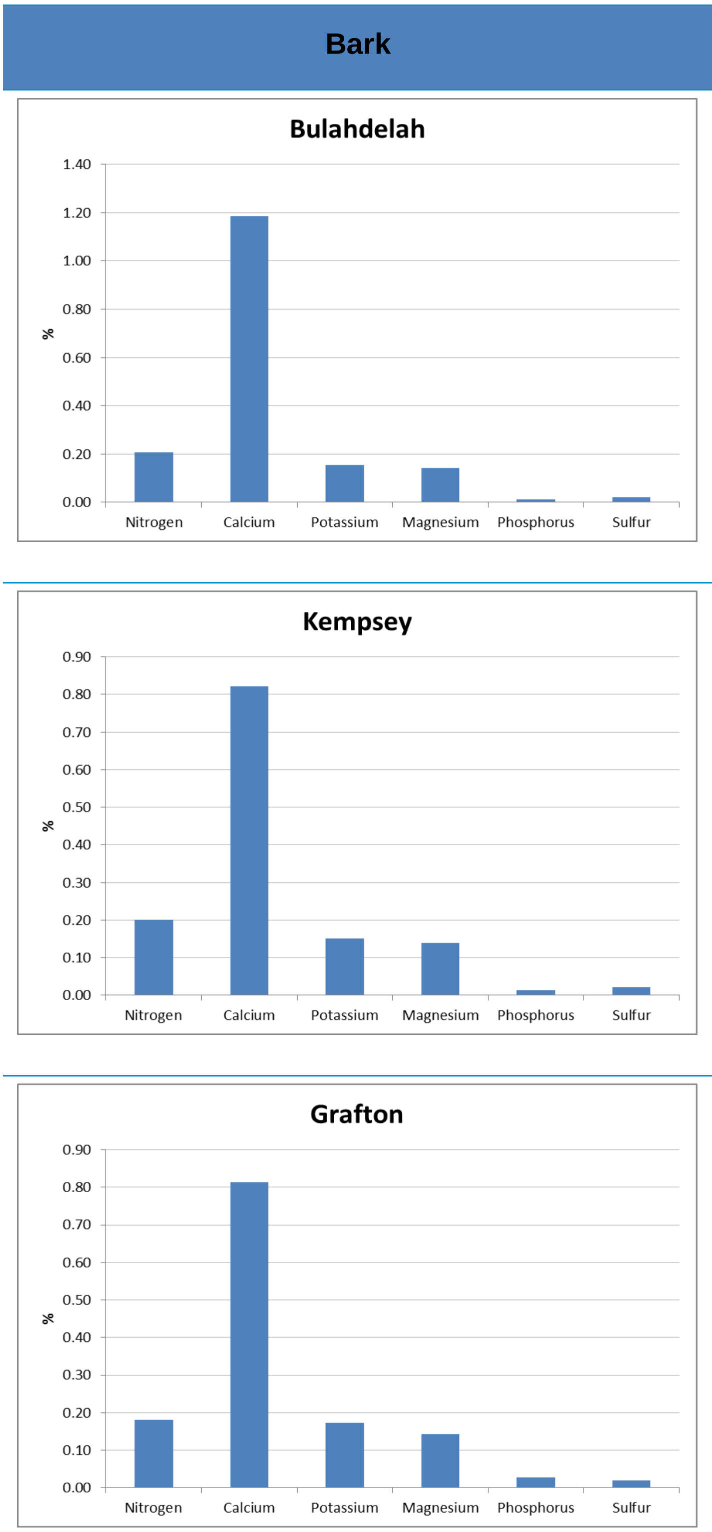
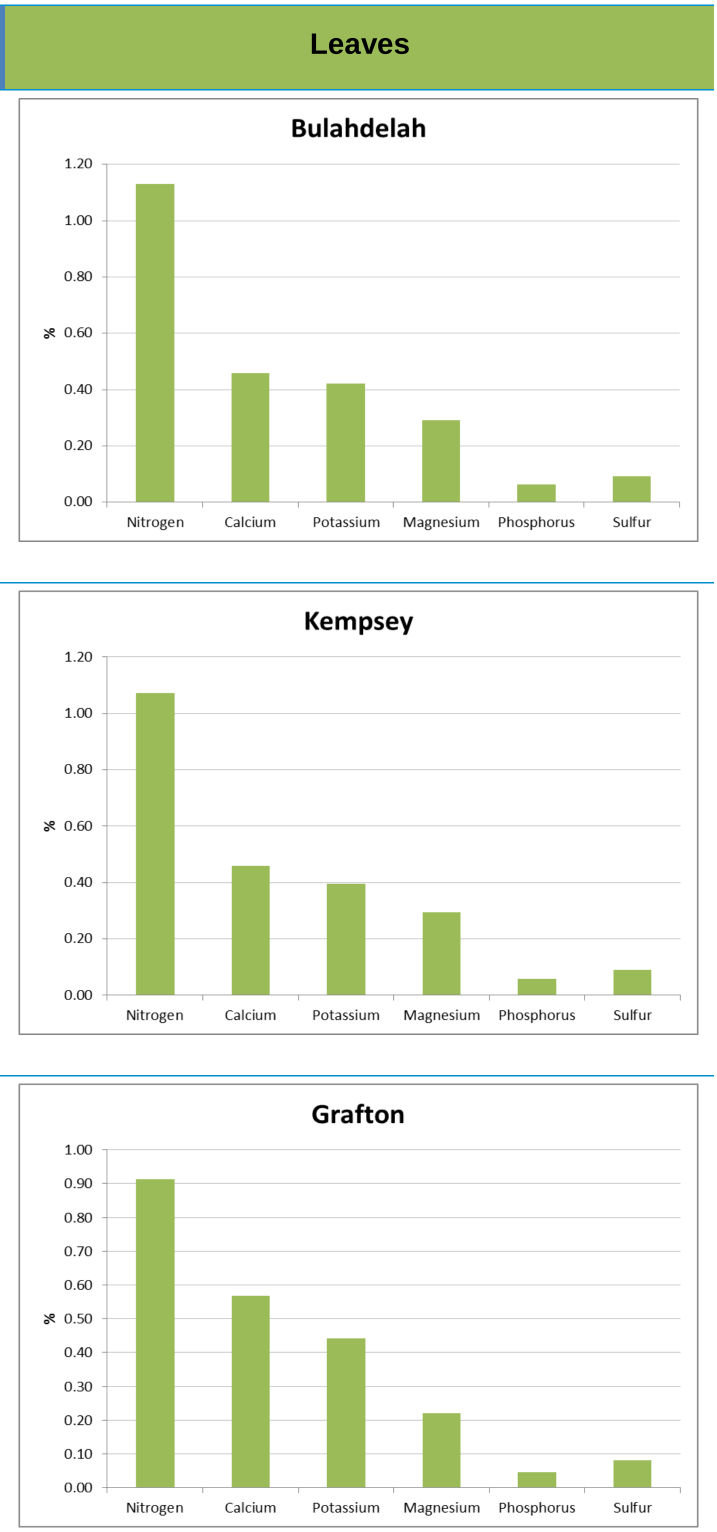


Figure 5.14 Leaves



Although not to the same level as in bark, calcium concentration was also high in branches (Figure 5.15). Nitrogen concentration in branches and bark were similar. The nutrient concentration of wood from Grafton was generally higher than for the other hubs, especially for calcium, potassium and magnesium (Figure 5.16). These differences were largely due to differences in the species mix for Grafton compared to other sites, where blackbutt accounted for a lower proportion of the overall biomass, and the concentration of calcium, potassium and magnesium was considerably lower for blackbutt wood compared to most other species.

Figure 5.15 Branches

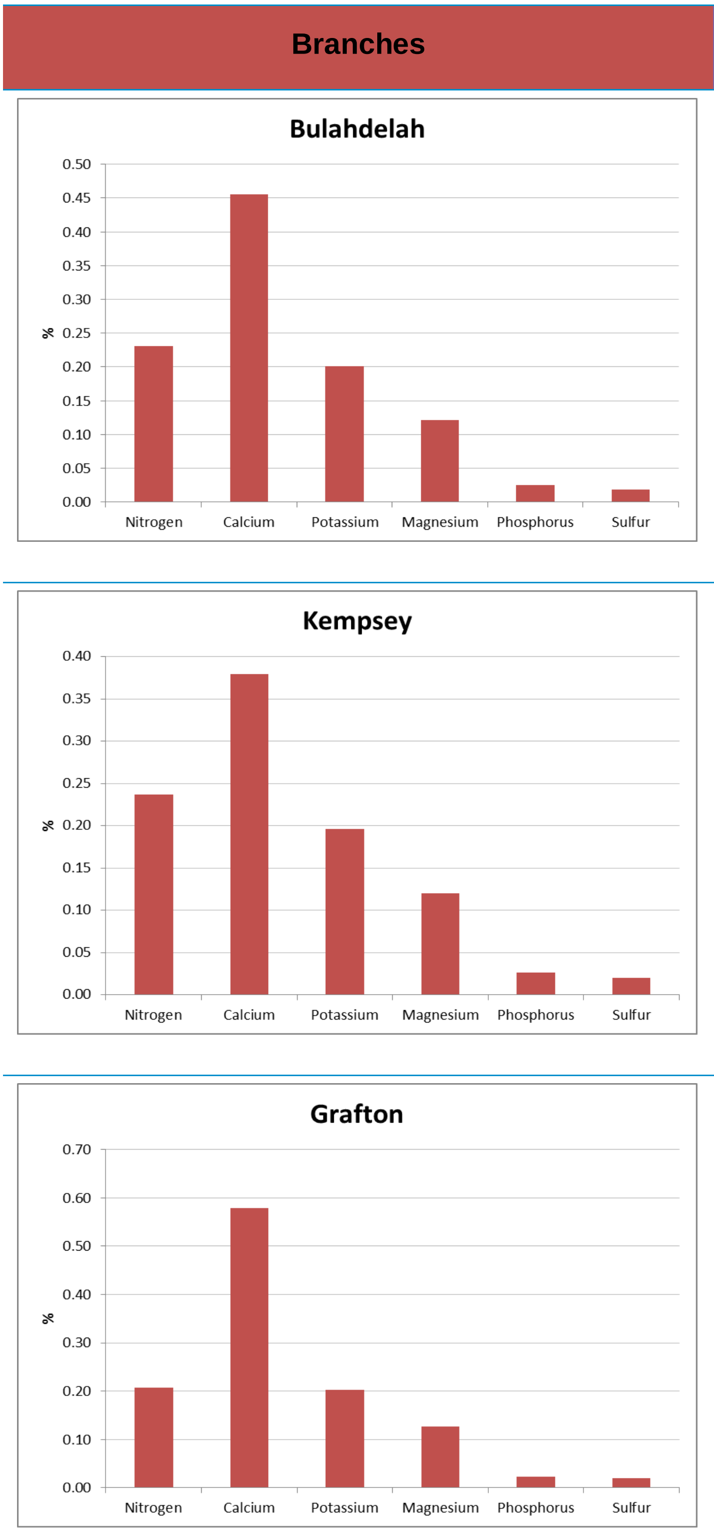
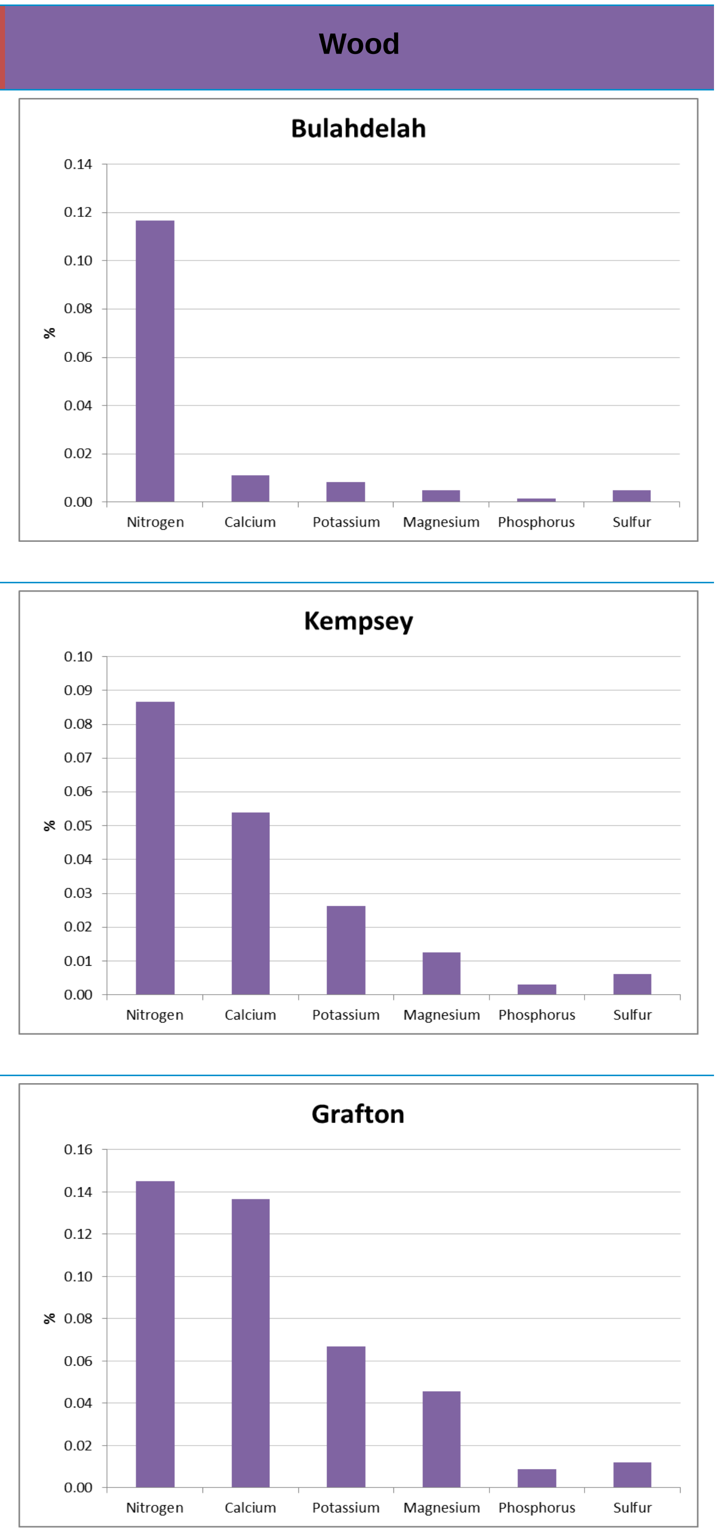


Figure 5.16 Wood



5.3.4 Nutrient losses due to harvest

Nutrient losses due to harvest varied according to nutrient type and region – for BAU harvest, the highest losses were of nitrogen, and the relative proportions ranged from 18.3% to 25.5% (Table 5.1). Harvest of biomass for bioenergy lead to similar losses (Table 5.1). For phosphorus, which is one of the key growth-limiting nutrients, losses ranged from 7-22% for BAU harvest with similar values for additional biomass extraction (Table 5.1). As additional biomass removal includes a proportion of large branches, this leads to typically higher losses of calcium, K and Mg compared to BAU harvest (Table 5.1). Overall losses of those nutrients though are of a lower scale than for N.

It is considered that net losses of phosphorus due to harvesting are inevitable – however, this may be a very long-term proposition for native systems with long rotations – decline in productivity due to P or any other nutrients has not been demonstrated for native systems[13]. The likelihood of loss of P leading to a decrease in productivity is low given that the estimated losses are at most, typically only 1-2% of the total P pool in many Australian forest soils[14]. However one needs to be cautious in evaluating this, as short and long-term nutrient availability are governed by physical, chemical and biological activity – a large proportion of the P in soil may be irreversibly fixed.

Calcium is relatively inert physiologically and may be accumulated in plants well in excess of requirement[15]. Whereas the distribution of Ca is largely extracellular, K is the most abundant cation within plant cells and has many physiological roles. Its loss may be more significant than Ca. However, nutrients such as potassium and magnesium are considered to be always in surplus in forests, irrespective of management regimes, due to input from rainfall[1]; thus their loss due to harvest activities represent less of a concern.

Table 5.1 Nutrient losses due to BAU harvest and the additional extraction of biomass for bioenergy from pulpwood.

Hubs	Harvest	% Nutrients removed					
		N	P	K	S	Ca	Mg
Bulahdelah	*BAU harvest*	23.0	7.0	5.0	14.2	1.8	4.1
	Biomass for bioenergy	19.3	11.1	11.9	14.5	11.3	9.4
Kempsey	*BAU harvest*	18.3	11.2	12.9	15.6	9.4	9.0
	Biomass for bioenergy	17.9	14.3	16.4	16.3	14.7	12.7
Grafton	*BAU harvest*	25.5	22.4	22.4	23.8	15.7	21.7
	Biomass for bioenergy	20.8	19.9	20.7	20.1	18.1	20.2

[13] Stewart, H.T.L. et al. 1985. On harvesting and site productivity in eucalypt forests. Search 16:206-210.
[14] Attiwill, P.M. and Leeper, G.W. 1987. Forest soils and nutrient cycles. Melbourne University Press.
[15] Marschner, H. 1986. Mineral nutrition in higher plants. Academic Press London.

5.4 General Discussion

In summary, there is no published evidence to our knowledge suggesting that managing native forests for production results in growth deficiencies due to nutrient loss. Natural nutrient inputs can be very significant and largely compensate for losses, especially for N. For example, it has been reported that N inputs due to rainfall can be in the order of 5 kg/ha/year for native systems (includes a value of 2kg / ha /year for biological nitrogen-fixation). Similar values have been reported for K, Ca and Mg. Natural input of P is much lower (0.02 kg/ha/year)[1].

This study provides a snapshot of the nutrient losses as a result of BAU harvest and additional harvest for biomass. A comprehensive nutrient budget analysis would consider long-term dynamics of losses (including any losses due to post-harvest regeneration burns) and inputs (e.g. via rainfall), which was outside the scope of this study. Regeneration burns oxidise much of the harvest slash and litter, and some nutrients (particularly N) are lost from the system by volatilisation and the convection of particulate matter. Where the regeneration burn is most intense, organic matter within a centimetre or more of the soil surface is also oxidised[1]. Losses of up to 200 kg /ha of N due to burning are typical for forest soils[16]. However, in contrast to native forests in Southern Australia, for the North Coast the area of forest in post-harvest burns is low, and where burnings are carried out they are of low-intensity. In some North Coast areas pre-harvest burns have been tested, with positive regeneration outcomes – this would be a preferable option from a nutrient retention perspective.

The results in this study suggest that the main potential losses due to additional biomass harvest for bioenergy would be of N, which is largely expected to be replenished naturally during the long native forest harvest cycles. Nevertheless, it would be prudent to monitor vigour of young regrowth stands covering sites of different productivity levels to detect any significant nutrient depletion issues. We do not expect this to be the case though, especially if nutrient-rich biomass fractions such as bark, leaves and small branches are retained in the forest, and post-harvest regeneration burns are restricted and kept at low intensities.

[16] Attiwill, P.M. 1985. Effects of fire on forest ecosystems. In: Research for forest management (Eds. J.J. Landsberg and W. Parsons). CSIRO Melbourne.

6. Ecological sustainability of harvesting native forest biomass for bioenergy

Brad Law, Caragh Threlfall

6.1 Background

Forest residue or fallen coarse woody debris (CWD) encompasses a variety of woody material, including fallen logs, branches and twigs, stumps, roots and fragments of fallen trees[17]. Because of its many roles, CWD is considered a critical structural and functional feature of many ecosystems[18,19]. CWD provides habitat for many components of biodiversity as it provides foraging, nesting/breeding opportunities and regeneration niches[20].

The attributes of CWD within an area vary depending on tree species, tree size at time of death, wood density and decay stage[4]. These factors, among others, play a role in governing the size, decay stage and presence of hollows in CWD[21]. Differences in CWD type are important to understand, as these attributes impact the utilisation of this resource by forest fauna.

To implement sustainable forest management practices, it is critical to understand the stocks and composition of CWD in managed areas in comparison to 'reference' (or unharvested) conditions. A better understanding is becoming increasingly important, as the removal of woody material from post-harvest forest residue in managed native forests has gained renewed interest as a way of meeting increased energy needs. It is important to note that the assessments of volumes of native forest harvest biomass potentially available for bioenergy as described in Section 1 relates to "pulp"-quality logs only.

Under the forest residues project we undertook three sustainability-related projects in north east NSW.

1. Benchmarking and modelling of forest residues in harvest and unharvested forests;
2. Assessing repeat timber harvests on CWD and fauna use of forest residue;
3. Preliminary assessment of the response of birds and bats to thinning of regrowth.

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[17] Woldendorp G. & Keenan R. J. (2005) Coarse woody debris in Australian forest ecosystems: a review. *Austral Ecol.* **30**, 834-43

[18] Harmon M. E., Franklin J. F., Swanson F. J., Sollins P., Gregory S., Lattin J., Anderson N., Cline S., Aumen N. G. & Sedell J. (1986) Ecology of coarse woody debris in temperate ecosystems. *Adv. Ecol. Res.* **15**, 133-302

[19] Lindenmayer D., Claridge A., Gilmore A., Michael D. & Lindenmayer B. D. (2002) The ecological roles of logs in Australian forests and the potential impacts of harvesting intensification on log-using biota. *Pac. Conserv. Biol.* **8**, 121-40

[20] Grove S. & Meggs J. (2003) Coarse woody debris, biodiversity and management: a review with particular reference to Tasmanian wet eucalypt forests. *Australian Forestry*, 258.

[21] Collins L., Bradstock R. A., Tasker E. M. & Whelan R. J. (2012) Impact of fire regimes, logging and topography on hollows in fallen logs in eucalypt forest of south eastern Australia. *Biol. Conserv.* **149**, 23-31.

6.2. Study 1: Benchmarking Forest Residues

We assessed the stocks and attributes of CWD across a range of wet and dry temperate native forests of eastern Australia. We used datasets collected from forests covering over 50 000 ha in northern New South Wales (NSW) to describe benchmark levels of CWD occurring in forests over extensive productivity, elevation and management gradients. We explored environmental variables that best explain CWD stocks (volumes and abundance) and type (decay stage and size class) and hypothesised that variables describing human disturbances (timber harvesting) drive CWD more than natural factors (topography, wildfire, stand characteristics), and that this influence is consistent across a range of forest types. We then compare the CWD estimates from this study area to other areas across Australia, in an effort to develop suitable benchmark estimates of CWD levels in managed forests.

Figure 6.1 Coarse woody debris provides important habitat for a range of fauna, including the iconic Hastings River Mouse and reptiles (bearded dragon)

6.2.1. Methods

To study a characteristic suite of forested vegetation types we used two existing regional scale data sets collected in north-eastern New South Wales (NSW), south-eastern Australia hereafter referred to as the escarpment and tableland forests dataset (Dorrigo region) and coastal lowlands and dissected ranges forests dataset (Clarence River catchment). CWD data from neither of these data-sets had previously been analysed. The data were collected across a range of forest types that had been subject to variable harvest intensity, from recently harvested areas, areas harvested between 5 – 30 years prior to data collection, and areas never subject to harvest to our knowledge (old growth). The data were also collected at a time when the pulpwood market was strong, but not in this region. Hence, it is unlikely pulp logs had been removed from these areas.

6.2.2. Key results and Discussion

A total of 5621 logs (> 30 cm diameter) were sampled during the surveys conducted in the Dorrigo area, of which 1114 were hollow-bearing (19.8%), and 884 were collapsed and highly decayed (15.7%). A total of 1266 logs (> 15 cm diameter) were sampled in the lowlands and dissected areas, of which 455 were hollow-bearing (36%), and 145 were collapsed and highly decayed (11.5%).

We found timber-harvesting was the dominant driver of CWD across all forest types, with almost double the count (pieces ha^{-1}) and volume (m^3ha^{-1}) of total CWD in selectively harvested than unharvested sites. We also found harvested sites had greater counts of hollow-bearing logs, and greater volumes of small and medium-sized CWD (15 – 50cm diameter) than unharvested sites. There was no effect of harvesting on the volume of large CWD (>51cm DBH). Total volumes of

CWD (> 15cm diameter) varied from an average of 114 m^3 ha^{-1} for unharvested sites and a mean of166 m^3 ha^{-1} for managed forests. These values are similar to those recorded in dry and wet sclerophyll forests elsewhere in Australia and are typical of global estimates for 'old growth' forests. The additional volume of CWD in managed forests comprised mostly small (15 – 30cm diameter 15.3 m^3 ha^{-1}) and medium sized material (31 – 50cm diameter 28.7 m^3 ha^{-1}).Using general linear models we captured up to 57 % of the variation in CWD across sites, and found that topography and the numbers of standing hollow-bearing and dead trees were also significant predictors of CWD. Surprisingly, we found little consistent effect of fire, and instead found timber harvesting was a more important driver of CWD volume. Further assessment of the effect of repeat timber harvesting on CWD is needed to fully understand its impact on CWD dynamics, especially if fallen CWD is removed from native forests for bioenergy production. This was assessed in our second project.

Further assessment of the effect of repeat timber harvesting on CWD is needed to fully understand its impact on CWD dynamics, especially if fallen CWD is removed from native forests for bioenergy production. Repeat timber harvests was assessed in our second project.

6.3. Study 2: An assessment of repeat timber harvests on CWD and fauna use of forest residue

Building upon knowledge generated from the study above, we assessed variation in CWD stocks, attributes and use by fauna in one of the study areas. In concordance with the scientific literature, we found above that harvest activities significantly influence CWD stocks, however little work has been conducted to assess the impact of repeat harvests on CWD, and the subsequent influence of this on habitat values. CWD is known to be a preferred habitat feature for many native animals, however the types of CWD most used or preferred by species is largely unknown. Studies from Tasmania suggest that CWD stocks in managed forests in Australia may decline over time from repeat harvest events, emphasising the need for a better understanding of the impact of multiple harvests on this resource across a range of Australian forests[4]. Subsequently, we assessed the effect of repeat timber harvest events on CWD and the use of different types of CWD by fauna.

6.3.1 Methods

We carried out this study in the coastal lowlands forests within Newfoundland State Forest and Yuraygir National Park, north of Coffs Harbour. A geographic information system (GIS) was used to identify suitable sites for this study based on fire history, forest type, topography and harvest history. We restricted our site selection to include only sites dominated by Blackbutt (*Eucalyptus pilularis*). Time since fire and fire frequency are factors known to influence the quality and amount of logs in a forest; hence to standardise their effects the study was confined to areas that had been most recently burnt between 2000 and 2004, 11-15 years prior to sampling, and excluded any area that had been burnt three or more times. We then used digitised and historic records of harvest events to obtain a detailed harvest history for the area. We excluded areas that had been harvested after 2010 to avoid any immediate impacts from recent harvesting events. We then assigned areas to one of four categories, based on the number of recorded harvest events: no record of ever being harvested; one recorded harvest event; two recorded harvest events; or three recorded harvest events. Potential sites that met these criteria were identified using GIS (n=200 potential sites), and a subset of these were selected in the field for use in the study. We established five plots in each harvest frequency treatment (unharvested; harvested once; twice; or three times; n = 20). Within each plot we assessed CWD stocks, and placed two motion-censored wildlife camera traps on two different types of logs for 49 nights during summer 2015-16. The two logs selected were of similar length and diameter (minimum length 2.5m, minimum small end diameter under bark 8cm), however were in different stages of decay. One log was selected to meet the criteria for “pulp” wood, being of the above dimensions, with no or little hollowing or fire damage, and did not have a greater than 50% sweep over 2.5m (was not curved). The other log selected was in a more advanced state of decay, with many fissures and hollows. We then compared differences in CWD attributes and log use by fauna in relation to differences in past harvest frequency.

6.3.2 Results

Average volume of all logs (including pulp-quality material) was 42.5 ± 7.3 m3 ha-1 (range 6.8 – 125), and volume of hollow-bearing logs was 63.4 ± 6.7 m3 ha-1 (40.8 %). There was a significant increase in the volume of non-hollow CWD in sites harvested three times versus unharvested sites, however we found no differences in the volumes of hollow-bearing CWD across harvest frequency. Repeat harvest activities increased the volume of CWD 15 – 30cm in diameter, but had no effect on other size classes. We also found sites with repeat harvest activities had significantly greater volumes of fresh, undecayed CWD, and that these sites had significantly lower understorey cover.

Figure 6.2 a sample of different species recorded by camera traps using coarse woody debris. From left to right: antechinus, northern brown bandicoot, brushtail possum, lace monitor.

We found no significant effect of harvest frequency of use of a site by fauna. Preliminary analysis suggests that logs containing a hollow, logs in a more decayed state and large logs are used significantly more frequently than other types of logs, especially by goannas, small mammals including Antechinus species and *Rattus fuscipes*, and skinks. Site level factors positively influencing fauna use of an area included the presence of piles of forest residues and increased understorey cover. We found no evidence that the total volume of CWD in a site influenced fauna use, or harvest history per se.

6.3.3 Discussion

This study confirms the previous findings that harvest activities generate specific types of CWD including smaller, less decayed material. We found no evidence that repeat harvest activities influence the volume of hollow-bearing or decayed CWD. Specific groups of fauna responded differently to log-level and site-level characteristics, however we found that logs were more likely to be visited by several different species when they contained a hollow, were larger and in a more decayed state. This suggests that CWD of this type should be retained or protected during harvesting operations, in addition to some portion of fresh CWD that over time will develop these characteristics.

6.4. Study 3: Preliminary assessment of the response of birds and bats to thinning of regrowth

One potentially important source of forest residue is from thinning operations in regrowth forest. The secondary regrowth that dominate stands post-harvesting comprise trees which are often uniform in age and size, creating a high density of stems with few canopy breaks[22]. Silvicultural thinning is often employed in such dense regrowth to reduce competition and encourage faster growth of mature, harvestable trees[23]. In addition to influencing tree growth, thinning has both direct and indirect effects including altering physical structure and composition of vegetation and modifying soil properties and microclimates[24]. Biological responses to thinning are complex with changes being detrimental to some taxa and beneficial to others[20]. The response of biodiversity to thinning in the coastal forests of NSW has received virtually no attention. Accordingly, we made preliminary assessments of the responses of bats and birds to thinning by supplementing existing studies that had not previously been analysed.

6.4.1 Methods

The study was carried out 200 km north of Sydney in an experimental section of Chichester State Forest. This area lies between 450-940 m in elevation and comprises small catchments where an experiment was established in 1974-75 to investigate the effects of harvest on water flow and quality (detailed site description can be found in Cornish 1993[25]). Regrowth originated from harvest that took place in 1983 as part of the original hydrology experiment, with two catchments left undisturbed[9]. Harvest involved clearfelling patches, but was not undertaken within 20 m either side of creek lines. One regrowth catchment (Kokata) was thinned in 2010 (27 years since harvest) to a target stem density of 200 stems ha-1 in order to encourage growth of remaining trees[26]. Thinning covered 21 ha of the Kokata catchment, representing 22 % of the catchment area. We used ultrasonic surveys of bats and visual/ aural surveys of birds before and after thinning to compare with surveys undertaken in adjacent unthinned regrowth and old growth forest. Sampling of bats was repeated before thinning in 2006 and 2007 and then twice post-thinning in 2011 (1-year post-thinning) and 2016 (6-years post-thinning).

Birds were counted on variable-radius plots centred at each of 24 census points throughout the study area. All birds seen or heard for 10 minutes within 50 m of the census points (0.78 ha) were recorded (within one of four distance categories from the plot centre). Census points were surveyed twice (once each by two observers) on separate days within the first five hours after sunrise, during each sampling period. The same two observers performed the counts each year to reduce problems associated with observer variability in bird counts. Bird counts were made during spring, coinciding with the peak in bird breeding activity. Counts were made in prior to thinning in 2003, 2005, 2007 and after thinning in 2015.

[22] Bauhus J., Puettmann K. & Messier C. (2009) Silviculture for old-growth attributes. *Forest Ecology and Management* **258**, 525-37

[23] Law B. S., Park K. J. & Lacki M. J. (2016b) Insectivorous bats and silviculture: balancing timber production and bat conservation. In: *Bats in the Anthropocene: Conservation of Bats in a Changing World* (ed T. K. C.C. Voight). Springer International Publishing, Cham, Switzerland.

[24] Verschuyl J., Riffell S., Miller D. & Wigley T. B. (2011) Biodiversity response to intensive biomass production from forest thinning in North American forests – A meta-analysis. *Forest Ecology and Management* **261**, 221-32.

[25] Cornish P. M. (1993) The effects of logging and forest regeneration on water yields in a moist eucalypt forest in New South Wales, Australia. *Journal of Hydrology* **150**, 301-22.

[26] Webb A. A., Kathuria A. & Turner L. (2012) Longer-term changes in streamflow following logging and mixed species eucalypt forest regeneration: The Karuah experiment. *Journal of Hydrology* **464**, 412-22.

Figure 6.3 Regrowth forest immediately after thinning in 2010 in Chichester State Forest.

6.4.2 Key Results

A total of 25,620 bat passes was recorded throughout the study from 11 taxa. Total bat activity was 70% greater on-tracks than off-tracks, emphasising the importance of linear edges for bats. Thinning significantly affected forest-use by bats and these effects were strongly modulated by the presence or absence of tracks. Off-track, bat activity was greater in unharvested areas than thinned and unthinned treatments. Although activity off-track in thinned regrowth was greater than unthinned regrowth, the time by treatment interaction was not significant, indicating the difference cannot be ascribed to thinning alone. Despite this, species richness was greater in thinned than unthinned regrowth (significant interaction), and this difference persisted for at least six years. Species composition in the thinned treatment more closely resembled unharvested forest. On-track activity was similar among treatments and typically high, except for thinned forest where activity and species richness was lowest.

A total of 71 bird species and 5028 individual birds were detected during formal surveys in this study. Thinning regrowth eucalypt forest had a generally positive effect on the bird populations in harvested wet sclerophyll forests of this study. However, some species either benefited or were disadvantaged depending on their habitat requirements. Nine species had sufficient data power to detect change, with five showing a positive response to thinning (Lewin's Honeyeater, Eastern Whipbird, White-browed Scrub-wren, Grey Fantail, Eastern Spinebill), three showing a neutral response (Brown Gerygone, Golden Whistler and Brown Thornbill) and one showing a negative response (Silvereye). However, it was also evident that a number of less common species were not detected on thinned sites after treatment (such as Logrunner, Mistletoe-bird, Satin and Regent Bowerbirds and Large-billed Scrub-wren).

6.4.3 Discussion

Our study, conducted over a 10-year period, is the first to assess changes to a bat community before and after thinning of forest regrowth. Without thinning, bat activity in harvested wet sclerophyll forests can take 33 years to return to levels recorded in unharvested stands[27].

[27] de Oliveira M. C., Smith G. C. & Hogan L. D. (1999) Current limitations in the use of bat detectors to assess the impacts of logging - a pilot study in south-east Queensland. *Australian Zoologist* **31**, 110-7.

Thinning of dense regrowth can restore foraging habitat for bats in managed landscapes where dense regrowth dominates, especially edge-space guilds[19]. However, we recorded a subdued, but positive, response of bat activity to thinning. This somewhat unexpected result may reflect insufficient sampling off-tracks in thinned areas to detect changes in habitat use or, alternatively, a response that is dependent on forest type. We suggest that carefully controlled experiments in additional forest types will be required to resolve the response of bats to thinning. We also emphasise the need to avoid felling hollow trees during thinning that could be used as roosts by bats including dead stems.

A number of common forest birds benefitted from the thinning while a number of less common species were not benefited in the time scale examined. In order to obtain sufficient data power to assess the precise impacts on a wider range of individual species, this and other studies need to be conducted on a larger scale, in a wider variety of habitats and over the full time scale of forest harvesting cycles.

7. Greenhouse gas implications of native forest residue management for North Coast forests

Fabiano Ximenes

7.1. Background

The removal of pulpwood from native forests for bioenergy will impact on the carbon dynamics in the forest, and also on the greenhouse gas (GHG) emissions from energy systems. Although many studies demonstrate the GHG benefits of using forestry residues for energy generation [28,29,30,31,32]; others argue that this practice does not result in GHG benefits, with some claiming worse outcomes than the use of coal for electricity generation[33,34,35].

In this study we adopt a life-cycle approach in considering the key GHG impacts associated with the use of biomass from native forests from the three regional hubs for energy generation. The assessment is restricted to the pulp-quality material that the various native forest types can provide, as detailed in Chapter 1.

7.2 System boundaries

There were three business as usual (BAU) scenarios which related to the biomass being left in the forest: 100% decay, 100% burning, 50:50 decay:burning (Figure 7.1). There were two bioenergy systems considered as end use for the biomass: electricity generation using wood pellets (displacing coal), and industrial heat generation in boilers (displacing natural gas and/or diesel). In the case of the use of wood pellets for electricity generation (Figure 7.1), this assessment included all relevant activities with a GHG impact, from the forest to "the power point". It is generally accepted that both hardwoods and softwoods are suitable for pellet production.

[28] Whittaker, C. et al. 2011. Energy and greenhouse gas balance of the use of forest residues for bioenergy production in the UK. Biomass and Bioenergy, 35: 4581-4594;

[29] Sathre, R. and Gustavsson, L. 2011; Time-dependent climate benefits of using forest residues to substitute fossil fuels. Biomass and Bioenergy, 35: 2506-2516.

[30] Ximenes, F., George, B.H., Cowie, A., Williams, J., Kelly, G. (2012). Greenhouse gas balance of native forests in New South Wales, Australia. Forests 3, 653-683.

[31] Wang, W.; Dwivedi, P. et al. 2015. Carbon savings with transatlantic trade in pellets: accounting for market-driven effects. Environ. Res. Lett. 10: 114019. doi:10.1088/1748-9326/10/11/114019.

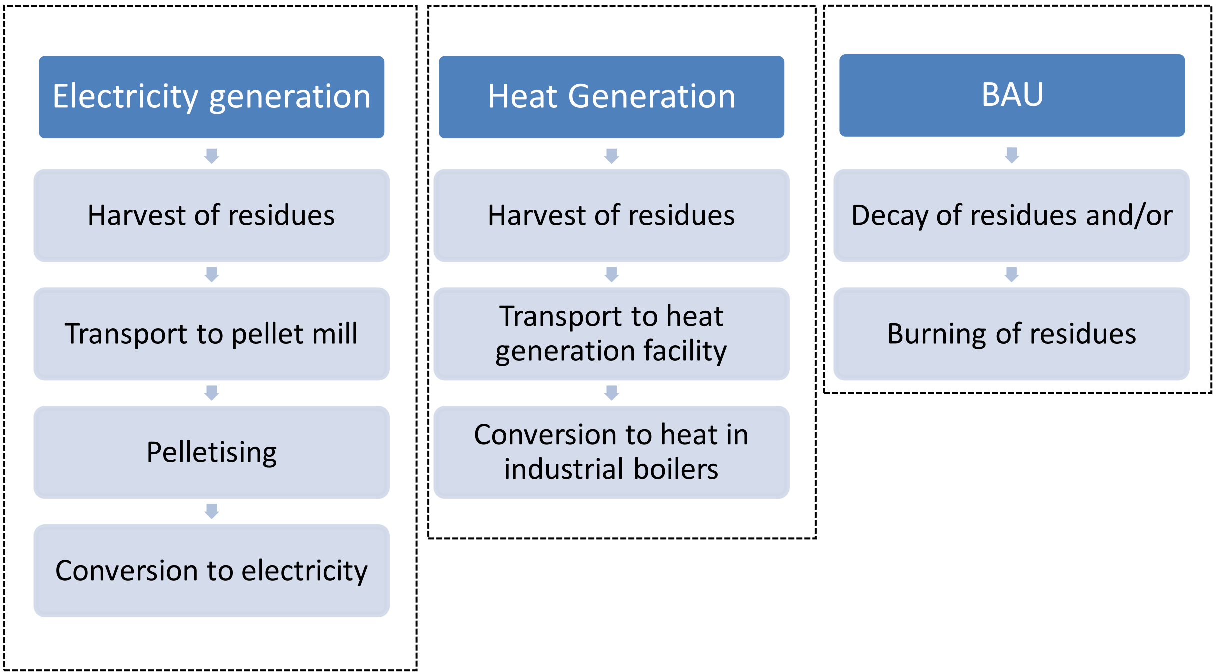
[32] Hanssen, S. et al. 2017. Wood pellets, what else? Greenhouse gas parity times of European electricity from wood pellets produced in the south-eastern United States using different softwood feedstocks GCB Bioenergy (2017), doi: 10.1111/gcbb.12426.

[33] Walker, T. et al. 2010. Biomass sustainability and carbon policy study. Brunswick, ME: Manomet Center for Conservation Sciences, http://www.mass.gov/eea/docs/doer/renewables/biomass/manomet-biomass-report-full-hirez.pdf

[34] Agostini, A., Giuntoli, J. and Boulamanti, A. (2013), Carbon accounting of forest bioenergy: Conclusions and recommendations from a critical literature review, p.16, European Commission Joint Research Centre, http://publications.jrc.ec.europa.eu/repository/bitstream/JRC70663/eur25354en_online.pdf

[35] Brack, D. 2017. Woody biomass for power and heat: impacts on the global climate. Research Paper Environment, Energy and Resources Department | Chatham House. https://www.chathamhouse.org/publication/woody-biomass-power-and-heat-impacts-global-climate

Figure 7.1 System boundary for the GHG assessment



The key parameters used in the calculations of the GHG balance of the different scenarios are listed in Table 7.1- Table 7.5. The volumes of biomass from native forests in the different hubs determined as available for bioenergy generation (Section 1) were used in the calculations of the GHG outcomes of the different scenarios tested. It is important to note that all CO_2 emissions related to the burning of wood to generate energy were included in the calculations of the GHG balance of energy systems. All results were expressed in terms of CO2-equivalents.

Table 7.1 Residue harvest parameters

	Value	Unit	Source
Harvest emissions	12	kg CO_2/m^3 of commercial logs (including pulp)	Ximenes et al 2012[3]
Proportion of harvest emissions associated with residue (pulp) extraction	20	%	Assumed
Moisture content of native hardwood	38	%	This study
Mean basic density of native hardwood	700	Kg/m^3	This study
Roundtrip distance	100	km	Ximenes et al 2012[3]
Emissions – transport from forest to energy facility (per roundtrip)	10	kg CO_2/m^3	Ximenes et al 2012[3]
Losses due to transport and handling (processing facility)	5	%	Assumed

Table 7.2 Burning emission parameters

	Value	Unit	Source
Wildfire burning efficiency*	44	%	Roxburgh et al 2015[36]
Methane emission factor	0.0126	g / kg dry timber	Roxburgh et al 2015
Methane global warming potential	25	CO2-e	IPCC (2006)[37]
Nitrous oxide emissions	0.0067	g / kg dry timber	Roxburgh et al 2015
Nitrous oxide global warming potential	298	CO2-e	IPCC (2006)

* This assumes that a proportion of the biomass does not get burnt and is subjected to decay processes

Table 7.3 . Biomass decay parameters

	Value	Unit	Source
Decay rate of coarse woody debris	14	%/year	FullCAM[38]
Atmospheric conversion of breakdown products	80	%	FullCAM
Proportion of biomass incorporated into soil	20	%	FullCAM

Table 7.4 Pelletising and electricity generation parameters

	Value	Unit	Source
Pellets required to generate electricity	0.537	Kg / Kwh	Röder et al 2015
Biomass required to dry pellets	0.18	t biomass / t of pellets	Röder et al 2015[39]
Electricity consumed in pelletising process	152.4	Kwh / t pellets	Röder et al 2015
GHG emissions due to electricity consumption in NSW	0.96	Kg CO_2-e/kwh	NGA (2016)[40]
Biomass losses in process (pelleting, chipping)	5	%	Röder et al 2015

[36] Roxburgh, S. et al. 2015. Review of fuel loads, burn efficiencies, emissions factors and recovery functions used to estimate greenhouse gas emissions and removals associated
with wildfire on temperate forested lands Prepared for the Department of the Environment . June2015, CSIRO.

[37] IPCC (2006), 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

[38] Commonwealth of Australia (Department of the Environment), (2017), http://www.environment.gov.au/climate-change/climate-science-data/greenhouse-gas-measurement/land-sector

[39] Röder, M., Whittaker, C. and Thornley, P. (2015), 'How certain are greenhouse gas reductions from bioenergy? Life cycle assessment and uncertainty analysis of wood pellet-to-electricity supply chains from forest residues', Biomass and Bioenergy, 79, http://dx.doi.org/10.1016/j. biombioe.2015.03.030

[40] Commonwealth of Australia (Department of the Environment), (2016), National Greenhouse Accounts Factors: Australian National Greenhouse Accounts: August 2016 Update, Commonwealth of Australia, August 2016.

Table 7.5 Industrial heat generation parameters

	Value	Unit	Source
GHG emissions due to combustion of wood in boilers	38.83	Kg CO2-e/t C in biomass used	Ximenes et al 2016 [41]
Energy content of biomass	10.4	GJ/t	NGA (2016)
GHG emissions due to combustion of natural gas in boilers	1067	Kg CO2-e/t C in biomass used	Ximenes et al 2016
GHG emissions due to combustion of diesel in boilers	1436	Kg CO2-e/t C in biomass used	Ximenes et al 2016
Proportion of gas to diesel boilers	80:20	ratio	Ximenes et al 2016

7.3 Results and Discussion

In Figure 7.2 the results for the GHG balance for the different scenarios are shown. Emissions due to the burning of 100% of the biomass in the forest result in the highest GHG emissions – however this needs to be interpreted with caution as in reality a proportion of the biomass may never burn. Emissions due to decay were approximately 15% lower than for burning. In practice, typically forests are subjected to a combination of decay and burning; thus the emission scenario for the “mix burn:decay” are considered to be more representative of the current BAU scenario.

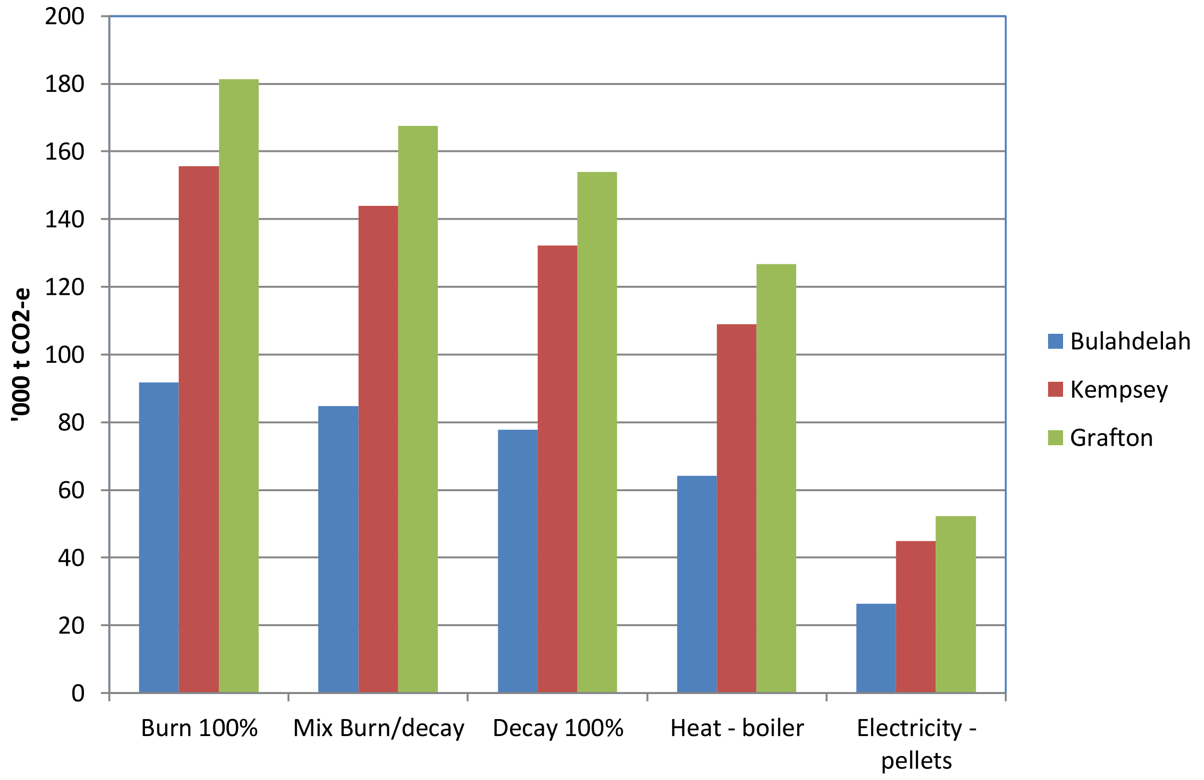
Harvest and transport emissions represented only a very small component of the GHG balance of the harvest system when the avoided emissions due to the displacement of fossil fuels are taken into account. The net GHG emissions associated with the use of pellets for electricity generation clearly resulted in the lowest GHG emissions, approximately 70% less than the BAU scenario and 60% less than for the use of biomass to generate heat in boilers (Figure 7.2). This difference in GHG outcomes between the use of biomass in boilers to produce heat and the use of pellets to generate electricity was primarily due to the much higher fossil fuel displacement benefits associated with electricity generation (displacing coal). The GHG emissions of coal use to generate electricity were approximately three times greater than the use of gas to generate heat. Harvest and transport emissions combined have a negligible impact on the GHG balance of both energy systems, accounting for 0.5-0.75% of the total GHG emissions (when CO_2 emissions from wood combustion are included in the calculations).

These results point to GHG benefits by using biomass for bioenergy from native forests pulpwood material even when the CO_2 emitted in the burning of the biomass is accounted for. In practice, the CO_2 released will be reabsorbed by the growing trees in sustainable harvest systems, eventually negating the impact of such emissions. In unsustainably harvested systems though, these emissions are especially significant as the carbon released in combustion is not replaced by carbon sequestered in growing trees. In the case of thinning material, removal of

[41] Ximenes, F et al 2016. Carbon stocks and flows in native forests and harvested wood products in SE Australia. Report prepared for Forests and Wood Products Australia (FWPA), January 2016. http://www.fwpa.com.au/images/resources/Amended_Final_report_C_native_forests_PNC285-1112.pdf

poorer quality trees may stimulate improved carbon sequestration outcomes in the remaining trees.

Figure 7.2 GHG balance of BAU and bioenergy generation scenarios for the use of pulpwood from regrowth native forests on the NSW North Coast.



To conclude, harvest of pulpwood from native forests on the NSW North Coast for energy generation as part of a sustainable, integrated sawlog-driven forest extraction system results in clear GHG benefits compared to current BAU scenarios. Further improvements on the GHG balance of harvest systems may be achieved by exploring opportunities for stockpiling biomass in the field to achieve some drying prior to transporting from the forest. This would have the effect of increasing transport efficiency, reducing GHG emissions due to transport and reducing energy requirements for drying the pellets, due to the lower moisture content of the biomass.

In addition to the direct climate benefits of displacing the use of fossil fuels, use of low-value wood for bioenergy has long-term silvicultural benefits, allowing the harvested forests to have a better chance of achieving positive regeneration outcomes, higher productivity, with associated higher carbon sequestration in managed stands.

8. General Discussion

This project has demonstrated the potential for the biomass that is currently under-utilised or wasted in the forest industry to be used as bioenergy or in other applications. Total available green harvest residue (within 100 km radius of the hubs) ranged from approximately 186,000 tonnes for Bulahdelah to 464,000 tonnes/year for around Grafton. The total estimated volumes for the North Coast are close to one million tonnes. The analysis has demonstrated that residue availability varies significantly according to the region. It is important to note that although based on best available knowledge and where possible on field measurements, the uncertainty around values used for the estimation of harvest residues may be high. The resource in the North Coast is hugely varied, with a range of different forest types sometimes found in the same small compartment of forest. Plantation residue volumes will vary depending on whether the total available residue is chipped on site or only “pulp-quality” logs are extracted. Markets for products also vary considerably depending on the region – for example a proportion of the lower value logs are processed by Weathertex in the Bulahdelah hub, whereas some biomass in the Grafton hub (plantations) is currently used for power generation in Queensland. This poses challenges for the accurate prediction of available biomass at any given time.

The harvest residues from private native forests were estimated using biomass recovery factors developed for the public native forest estate. Given the significance of the private native forestry resource, it would be desirable to work with specific private properties in the respective hubs to refine the estimates provided here. In addition to the traditional biomass sources, there is potential for non-forestry biomass derived from agricultural crops, orchards, urban tree trimming and organic waste sent to landfill. Another possible source that may be available in the future is biomass removed mechanically for bushfire control in areas near communities or significant infra-structure where hazard-reduction burns are difficult to implement. This is currently been trialled in Wauchope.

Sawmill residues (green) were estimated to range between 46,000 tonnes for around Bulahdelah to 118,000 tonnes/year for facilities around Kempsey (100 km radius). Green offcuts represented approximately 68% of the total volume of green residues produced. Current markets for some of the green residues vary depending on location; the power/heat market is stronger further up North, whereas landscaping markets are strong for processors within 150km of Bulahdelah, especially those closer to Sydney.

Preliminary estimates from the residue valuation work suggest that the average weighted costs (delivered prices) for biomass in the form of woodchips from harvest operations and sawmills range from $55/tonne of chips for biomass within 50 km of Kempsey, to $76/tonne of chips for biomass within 150 km of Bulahdelah. These values include native and plantation forest residue volumes and mill residues. When mill residues are excluded weighted average prices increase, typically ranging between $70 and $80/tonne of chips. There is a clear trade-off between distance and total volumes, but the prices estimated here are within expected ranges for the resource.

The total volume of harvest residues from forestry operations is enough to support the establishment of at least six average-sized pellet production facilities (producing 100,000 tonnes of pellets / year). As approximately 0.5 tonnes of pellets are required to produce 1 Mwh of electricity, we estimate a typical facility would produce enough pellets to generate the equivalent of close to 200 GWh of electricity. To put it into context, that is equivalent to the annual electricity consumption of approximate 35,000 homes in NSW. The combined capacity of six facilities would produce enough electricity for approximately 200,000 homes. Demand for pellets for electricity generation overseas is increasing significantly (particularly in Europe, Japan and South Korea). The creation of a strong demand for pellets for large-scale electricity generation domestically in Australia would provide further impetus and interest in the use of the existing biomass. Novel concepts such as the development of smaller scale, solar:biomass power generation plants for regional areas may also be considered attractive in the near future.

The potential use of the biomass for bioenergy goes beyond electricity generation. There may be opportunities in biofuel production (e.g. ethanol, bio-oil from fast-pyrolysis). The biomass from forest harvest residues alone would support six ethanol-producing facilities (100,000 dry tonnes /year), each producing approximately 25-30 ML/year (sales of ethanol in NSW are around 360 ML/year[42]). The use of industrial boilers for heat generation is a well-established practice, there is also significant room for the conversion of gas and diesel fuelled boilers to biomass. The estimated available biomass would be able to support the use of boilers to heat many public Olympic-sized pools. A typical system has a 600 kW capacity, requiring approximately 600 tonnes of woodchips for six months[42].

In addition to energy generation opportunities, our analyses have shown significant potential for the extraction of high-value chemicals from native hardwoods on the North Coast. Though initial results are promising, a more targeted and intensive study is required, involving the analysis of viability of production in facilities located next to existing wood-processing facilities. As the concentration of compounds of interest tends to be small, this would provide an opportunity for the development of combined facilities where high-value chemicals are produced, with the remaining biomass used for power or heat generation.

Removal of additional biomass for bioenergy from native forests will inevitably result in an increased loss of nutrients, the losses are typically greater for nitrogen, which is largely expected to be replenished naturally during the longer native forest harvest cycles. Retention and management of bark on site, retention of leaves and minimising post-harvest regeneration burns are identified as key actions to minimise any impacts. It is instructive to note that in the many areas where pulp has been harvested for considerable periods of time, there has been no evidence in the field that regeneration and regrowth have been compromised.

The biodiversity component of the research confirmed expectations that managed native forests typically support higher volumes of CWD than unmanaged forests, and that CWD provides habitat for a wide range of species. Accordingly, residue should not be considered waste. From a habitat provision perspective, large CWD pieces are especially important. The benchmarking data presented provide good estimates of expected natural volumes of CWD in different forest types that could be used in formulating recommendations for retention levels of CWD required to minimise habitat loss. As part of this process, we also recommend considering the local landscape level, which includes environmentally sensitive areas that are excluded from harvesting, such as riparian zones. Further data on the CWD requirements of priority threatened species, such as the Hastings River Mouse, would assist in development of robust recommendations.

[41] https://www.ipart.nsw.gov.au/files/sharedassets/website/trimholdingbay/final_report_ethanol_supply_and_demand_in_nsw_-_march_2012.pdf

[42] http://www.mountgambier.sa.gov.au/webdata/resources/files/Case%20Study-Mount%20Gambier%20Aquatic%20Centre%20Biomass%20Boiler.pdf

One of the common concerns raised in utilising biomass from native forests for bioenergy generation is the impact on climate change. The analyses carried out here clearly shows that, from a climate perspective, the use of biomass that would have otherwise been left in the forest to burn and/or decay for bioenergy generation results in positive outcomes, especially if biomass is used to produce electricity displacing the use of coal. This is consistent with a previous study (Ximenes et al 2012), where the positive contribution of increased biomass usage for energy generation from native forests for climate mitigation was also clearly demonstrated.

The key aim of this project was to provide information on the extraction of forestry biomass for bioenergy on the NSW North Coast, so that potential investors can have greater confidence in the residue availability for each of the hubs. The analytical framework now in place allows the derivation of potential available volumes in the vicinity of any major regional town of interest in the North Coast. Further work is required to determine residue availability in other important native forest wood-producing areas of the State, such as the south coast and western region, to continue supporting the creation of new markets for biomass from sustainably managed forests.

9. FAQs

These FAQs were compiled to provide a quick answer to likely questions around the potential for biomass from the NSW North Coast to be utilised for bioenergy generation and/or the extraction of high-value chemicals.

1) Is there enough biomass in residues to support industrial scale bioenergy generation on the NSW North Coast?

Yes – the volumes available would be enough to support, for example, at least six average-sized pellet production facilities (producing 100,000 tonnes of pellets / year), with enough combined electricity generation potential to supply annual electricity needs of over 200,000 homes in NSW; or six ethanol-producing facilities (100,000 dry tonnes /year), each producing approximately 25-30 ML/year

2) Where are the highest volumes – plantations, native forests or sawmills?

The absolute volumes of forestry residues will vary according to forest location, size of the hub and existing markets. Volumes of harvest residue biomass from native forests (including public and private) were much higher than for sawmills and plantations.

3) Is it economically viable to remove the biomass from the forest for bioenergy?

Yes – but that will ultimately depend on a number of factors, including the source of residues – the costs of sourcing biomass from harvest residues will invariably be higher than sourcing residues from sawmills. It is important to note that pulp logs were previously transported distances greater than the maximum distance used on our study (150km) to be woodchipped and sent to Japan. Also it is important to note that it is economically viable to move biomass for 700-800 km in North America and ship it to the UK for energy generation.

4) What is the typical moisture content of harvest residues?

The average moisture content of native hardwood species sampled from the different hubs was 38% (wet basis). The moisture content of plantation wood is higher; in a study we conducted for plantation blackbutt the average moisture content (wet basis) was 44%, with plantation pine typically having higher moisture content (around 50%).

5) What is the calorific value of the wood produced on the North Coast?

The calorific value of samples collected from a range of hardwoods did not vary much, ranging from 18.6 Mj/kg for blackbutt to 19.3 Mj/kg for red mahogany.

6) Aren't sawmill residues largely utilised already?

Yes – residues generated from "dry mill" processing are largely already committed, and to some extent a significant proportion of green residues as well. However many of the current uses for the green mill residues are for low-value applications.

7) Which region (s) is the biomass hotspot?

Grafton is the region with highest overall volumes available – but the study showed high volumes in all hubs.

8) Is biomass extraction for bioenergy likely to lead to nutrient deficiency in native forests?

There is no evidence to support this. Although our results show that nitrogen in particular is depleted to a significant extent immediately after harvest, these losses are largely expected to be replenished naturally during the long native forest harvest cycles.

9) Can biomass extraction for bioenergy occur without compromising forest biodiversity values?

Yes – the research confirmed the expectation that managed native forests typically support higher volumes of coarse woody debris (CWD) than unmanaged forests, and that retention of large CWD on site would have the greatest habitat value. Suitable guidelines will be needed to ensure appropriate levels of CWD are retained to provide habitat.

10) What is the better option for climate mitigation – leaving residues in the forest or using it for bioenergy generation displacing fossil fuels?

Our analysis clearly demonstrates that use of residues for bioenergy leads to superior climate mitigation results.

11) What are the best potential uses for the biomass – electricity generation, industrial heat, biofuels?

That will depend on a number of factors – e.g. local mix of energy sources; demand, transmission networks, types of industries present. For three main potential uses there is no clear preference based on the feedstocks alone; market forces will dictate where biomass will eventually be used.

12) Is it worth considering the use of residues for the extraction of high-value chemicals?

Yes; results here, though preliminary, suggest that further consideration of the potential for high-value chemical extraction from NSW North Coast native hardwoods is warranted.