Appendix I. Domestic Fuelwood Questionnaire - Stage 1

Department of Ecosystem Management,
University of New England,
Armidale, NSW, 2351.
Ph. 73 3365.

February, 1991.

Dear Resident,

I am currently studying the use of fuelwood (firewood) by residents of Armidale as part of a research programme on rural forestry. Little is understood about the annual consumption of fuelwood, preferred species, the main harvesting areas and the sustainability of local fuelwood trees into the 21st century. These are important questions. Wood provides an inexpensive and effective source of domestic energy and could be managed to ensure continuous production for all time.

As part of the study, 1000 Armidale residences (from a total of about 7000) including your own were selected at random to participate in the domestic fuelwood survey attached. Please read the enclosed survey and answer the questions. It will take about 10 minutes to complete and your information will remain strictly confidential. After completing the form, simply retain it until collection from your residence the following day.

I appreciate your involvement in this study. If you would like further information about the work, please contact me at the above address.

Yours sincerely,

Mr. Julian Wall.

DOMESTIC FUELWOOD QUESTIONNAIRE

Note: If you find that more than one answer is correct for a question, please tick each of the appropriate boxes. Comments on any of the questions are welcome and may be written alongside the answer.

A. ABOUT YOUR RESIDENCE

1. Address of residence ______________________________.
______________________________.

2. Approximately how old is the dwelling? ____ years.

3. What is the main construction material of the walls?

☐ brick ☐ fibro ☐ timber

4. Does the dwelling have insulated ceilings or roof?

☐ yes ☐ no ☐ don't know

5. Does the dwelling have insulated walls?

☐ yes ☐ no ☐ don't know

6. How many bedrooms are there in the dwelling? ______.

7. How many people are residing in the dwelling this year?

☐ adults ☐ children (under 18 years)

B. ENERGY USE INSIDE THE HOUSEHOLD

8. Does the dwelling have a fireplace or wood-burning appliance of any kind?

❒ yes ❒ no

If yes, please go to ***Q.9*** *now and continue.*

If ***no****, please complete the following table by ticking one box in each column and refrain from answering further questions.*

Main Energy Source	Space heating	Cooking	Hot water
Electricity	❒	❒	❒
Gas	❒	❒	❒
Oil	❒	❒	❒
Coal	❒	❒	❒
Solar	❒	❒	❒

9. Please indicate the total number of fuelwood appliances inside the house and the rooms in which they are located (eg. kitchen).

Note: 'slow combustion heater' refers to the old-styled non-cooking wood heater, usually very heavy and constructed of cast iron. 'Kent heater' refers to the modern type non-cooking wood-heater. Wood stove refers to appliances designed for cooking as well as heating.

	Tot.No	No Used	Room(s)
open fireplace	______	______	__________________.
wood stove	______	______	__________________.
slow combustion heater	______	______	__________________.
pot-belly stove	______	______	__________________.
kent heater (or equivalent)	______	______	__________________.
other: ______________ (please specify)	______	______	__________________.

10. What is the <u>major</u> source of heating in your <u>main living area</u>? (bedrooms are covered separately in Q.13).

- ☐ electricity ☐ gas
- ☐ oil ☐ coal
- ☐ solar ☐ fuelwood
- ☐ other (please specify): ________.

11. What <u>supplementary</u> forms of energy are used for space heating in the <u>main living area</u>?

- ☐ electricity ☐ gas
- ☐ oil ☐ coal
- ☐ solar ☐ fuelwood
- ☐ other (please specify): ________.

12. What type of fuelwood heating device is used for space heating in the <u>main living area</u>?

- ☐ open fireplace ☐ slow combustion heater
- ☐ wood stove ☐ pot-belly stove
- ☐ kent heater ☐ NONE
- ☐ other (please specify): ________.

13. Please complete the following table for fuelwood heating of all <u>bedrooms</u> in the household by ticking the appropriate box in each column.

	BEDROOM				
	1	2	3	4	5
fuelwood = main form of heating	☐	☐	☐	☐	☐
fuelwood = supplement heating only	☐	☐	☐	☐	☐
fuelwood not used for heating	☐	☐	☐	☐	☐

14. Please tick the months in which fuelwood is burnt regularly for interior heating in the household.

- ☐ January ☐ February ☐ March
- ☐ April ☐ May ☐ June
- ☐ July ☐ August ☐ September
- ☐ October ☐ November ☐ December
- ☐ never

15. What is the main form of energy for water heating in the house?

- ☐ electricity ☐ gas
- ☐ oil ☐ coal
- ☐ solar ☐ fuelwood
- ☐ other (please specify): ___________.

16. What secondary forms of energy are used for water heating in the house?

- ☐ electricity ☐ gas
- ☐ oil ☐ coal
- ☐ solar ☐ fuelwood
- ☐ other (please specify): ___________.

17. When is fuelwood used for hot water in the residence?

- ☐ all year ☐ winter only ☐ occasionally
- ☐ never
- ☐ other (please specify): ___________.

18. What is the main form of energy for cooking in the house?

- ☐ electricity ☐ gas
- ☐ oil ☐ coal
- ☐ solar ☐ fuelwood
- ☐ other (please specify): ___________.

19. What secondary forms of energy are used for cooking in the house?

- ☐ electricity ☐ gas
- ☐ oil ☐ coal
- ☐ solar ☐ fuelwood
- ☐ other (please specify): ___________.

20. When is fuelwood used for cooking in the residence?

- ☐ all year ☐ winter only ☐ occasionally
- ☐ never
- ☐ other (please specify): ___________.

C. FUELWOOD SELECTION FOR THE RESIDENCE

21. How do you obtain fuelwood?
Please rank those items relevant to you in order of importance, starting with 1 (most important)

- ☐ cut your own from State Forest
- ☐ cut your own from roadsides
- ☐ cut your own from friends' property
- ☐ delivered free-of-charge by a friend
- ☐ purchase offcuts from Armidale sawmill
- ☐ purchase from and delivered by a commercial fuelwood supplier.
- ☐ other (please specify): ________________________________.

22. What type of wood did you burn indoors in 1990?

☐ stringybark	☐ box	☐ ironbark
☐ red gum	☐ white gum	
☐ pine	☐ offcuts	☐ briquettes

- ☐ other (please specify): ________________.
- ☐ don't know

NOTE : A supplementary questionnaire will be distributed in April-June and September-November 1991. It will consist of 5 short questions concerning fuelwood used in your household this year. Your involvement in this component of the survey would also be appreciated as it will help determine the total tonnage of fuelwood used in Armidale. Please tick the box if you are prepared to receive the supplementary questionnaire.

☐

Thankyou for participating.

Appendix II. Domestic Fuelwood Questionnaire - Stage 2

Department of Ecosystem Management,
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Ph. 73 3365.

May/June/July, 1991.

Dear Resident,

I wish to thankyou for participating in the fuelwood questionnaire distributed in February/March. As you know, supplementary surveys are being distributed to obtain information on amount of firewood consumed. There will be two such surveys - attached is the first. Being a user of fuelwood, your participation in this component is very much appreciated. It will help determine the total tonnage of fuelwood used in Armidale this year and such information will assist in the development of a rural plantation strategy to ensure production for all time.

Please read the enclosed survey form and answer the questions. It will take about 10 minutes and your information will remain strictly confidential. After completing the form, simply place it in your letterbox for retrieval the following morning. I appreciate your involvement in this study. Please contact me at the above address if you would like further information about the work.

Yours sincerely,

Mr. Julian Wall.

<u>DOMESTIC FUELWOOD QUESTIONNAIRE</u> - <u>May/June</u>

Address of residence ______________________________.
______________________________.

For how long have you lived at the residence? ____ years/months.

For how long have you been burning wood at the residence? ____ years/months.

If applicable, estimate how many tonnes of firewood you used last year (1990).

______ tonnes.

Please Note: Complete Section A if you buy fuelwood from a commercial supplier.
Complete Section B if you purchase timber from Armidale sawmill.
Complete Section C if you cut your own fuelwood.
Complete 1 or more Sections.

SECTION A : Please complete this section if you purchase wood from a commercial supplier.

1. Have you purchased any fuelwood for use in 1991?

   ☐ yes

   ☐ no

   If no, refrain from answering further questions in Section A. If yes, please continue.

2. In the following space, please indicate the quantity of fuelwood purchased to date (for use in 1991) (examples: 3 tonnes; 1 tonne and 1 trailer load; 3 ute loads; etc.)

3. What type of wood was purchased (tick 1 or more)?

   ☐ stringybark ☐ box (yellow/white)

   ☐ red gum ☐ ironbark

   ☐ don't know

   ☐ other (please specify): ___________.

4. When was the wood purchased?

   ☐ last year

   ☐ January ☐ February ☐ March

   ☐ April ☐ May ☐ June

5. Was the wood purchased split or unsplit?

   ☐ split

   ☐ unsplit

6. Was the wood cut to a length suitable for use in a kent heater, slow combustion stove, wood stove or other closed fuelwood appliance?

   ☐ yes

   ☐ no

7. What was the full purchase price? $ _____.

SECTION B : Please complete this section if you purchase wood (offcuts) from Armidale sawmill.

8. Have you purchased any offcuts for use as fuelwood in 1991?

   ❒ yes

   ❒ no

   If no, refrain from answering further questions in Section B. If yes, please continue.

9. In the following space, please indicate the quantity of offcuts purchased to date (for use in 1991) (examples: 3 tonnes, 3 trailer loads; a 4-tonne truck load; etc)

10. When was the wood purchased?

    ❒ last year

    ❒ January ❒ February ❒ March

    ❒ April ❒ May ❒ June

11. What was the full purchase price? $ _____.

SECTION C : Please complete this section if you collect your own fuelwood.

12. Have you collected any fuelwood for use in 1991?

- ❐ yes
- ❐ no

If no, refrain from answering further questions in Section C. If yes, please continue.

13. How many times have you collected firewood for use this year? ____.

14. On average, how far do you travel to collect your firewood (round trip)?

_____ (kilometres/miles)

15. In the following space, please indicate the quantity of fuelwood collected to date (for use in 1991) (examples: 2 ute loads; 3 trailer loads; a 4-tonne truck load; 5 tonnes; etc)

16. When was the wood collected?

- ❐ last year

❐ January	❐ February	❐ March
❐ April	❐ May	❐ June

17. If you were charged to collect the wood, please specify the price.

$ ____.

18. Please indicate your view on wood availability during the years in which you have collected.

- ❐ much more available
- ❐ more available
- ❐ unchanged
- ❐ less available
- ❐ much less available

Why? ____.
____.
____.
____.

Appendix III. Domestic Fuelwood Questionnaire - Stage 3

Department of Ecosystem Management,
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Ph. 73 3365.

October/November, 1991.

Dear Resident,

Please find attached the third and final firewood questionnaire. After completing this form, simply place it in your letterbox for retrieval the following morning. Thank you for participating in this study.

Yours sincerely,

Mr. Julian Wall.

<u>IMPORTANT</u> - **On _______ 1991 you completed the 2nd firewood questionnaire. At that time you had bought/collected _____________ of firewood in ________ . When filling out the remainder of this survey form, <u>DO NOT</u> include this firewood. Only include firewood which you have bought/collected subsequently.**

DOMESTIC FIREWOOD QUESTIONNAIRE - October/November

Address of residence ____.

____.

If applicable, estimate how many tonnes of firewood (on average) you use per year.

____ tonnes.

Were there any periods of time during your 1991 burning season in which wood was not burnt? (e.g. you were on holidays).

☐ yes

☐ no

If yes, please indicate how many weeks ______.

There are many arguments for and against the use of firewood for domestic heating, compared with other forms of energy (eg. electricity, gas, oil). Please indicate your reasons or preferences for using firewood.

____.

____.

____.

____.

Please Note: Complete Section A if you buy firewood from a commercial supplier.
Complete Section B if you purchase timber from Armidale sawmill.
Complete Section C if you cut your own fuelwood.
Complete 1 or more Sections.

SECTION A : Please complete this section if you purchase wood from a commercial supplier.

1. Have you purchased any additional firewood since completing the 2nd firewood survey?

   ❐ yes

   ❐ no

   If no, refrain from answering further questions in Section A. If yes, please continue.

2. In the following space, please indicate the quantity of additional firewood purchased (examples: 3 tonnes; 1 tonne and 1 trailer load; 3 ute loads; etc)

3. What type of wood was purchased (tick 1 or more)?

   ❐ stringybark ❐ box (yellow/white)

   ❐ red gum ❐ ironbark

   ❐ don't know

   ❐ other (please specify): __________.

4. When was the wood purchased? (tick 1 or more).

   ❐ April ❐ May ❐ June

   ❐ July ❐ August ❐ September

5. What was the full purchase price? $ _____.

SECTION B : Please complete this section if you purchase wood (offcuts) from Armidale sawmill.

6. Have you purchased any offcuts from Armidale sawmill since completing the 2nd questionnaire?

❐ yes

❐ no

If no, refrain from answering further questions in Section B. If yes, please continue.

7. In the following space, please indicate the quantity of offcuts purchased (examples: 3 tonnes, 2 ute loads; 3 trailer loads; a 4-tonne truck load; etc)

8. When was the wood purchased?

❐ April	❐ May	❐ June
❐ July	❐ August	❐ September

9. What was the full purchase price? $ _____.

SECTION C : Please complete this section if you collect your own firewood.

10. What type of vehicle do you use for firewood collection?
(eg. '87 Ford Falcon; '78 Toyota Land Cruiser)

______________________________________.

11. What is your vehicle's engine capacity?
(e.g. 4 cyl. 2.0L ; 8 cyl. 5.0L)

__________.

12. What is your vehicle's fuel consumption (approx.)?
(please disregard this question if you don't know)

__________ miles.gal / km.litre.

13. Have you collected any firewood since completing the 2nd firewood questionnaire?

❐ yes

❐ no

If no, refrain from answering further questions in Section C. If yes, please continue.

14. How many times have you collected firewood since completing the 2nd questionnaire? ______.

15. In the following space, please indicate the quantity of firewood collected.
(examples: 2 ute loads; 3 trailer loads; a 4-tonne truck load; 5 tonnes; etc)

16. When was the wood collected?

❐ April ❐ May ❐ June

❐ July ❐ August ❐ September

Appendix IV. Fuelwood Merchant Questionnaire

1. For how long have you been cutting wood in the New England region? ____ years.

2. On average, how many tonnes do you cut per year? _____ tonnes.

3. Do you harvest timber from more than 1 place?
   ❒ yes ❒ no

   If *yes*, how many? ____ .

4. What type of vehicle do you use for the business? ________________________.

5. What is the vehicle's load capacity? ______ tonnes.

6. What is the vehicle's fuel efficiency? _____ (m.p.g. or km/l).

7. How many tonnes of firewood can be cut from a typical tree that you harvest?
   _____ tonnes.

8. Do you make use of greenwood for firewood?
   ❒ yes ❒ no

9. For how long is wood dried before sale? _____ months.

10. Do you split firewood for customers?
    ❒ yes ❒ no

    If *yes*, what do you use to split wood?
    (please specify):_________________.

11. Are you concerned about the availability of wood into the future? (please comment on your answer).
    yes ____.
    ____.
    no ____.
    ____.

12. Do you think any measures should be taken to ensure firewood production in future years?
    ❒ yes ❒ no

    If *yes*, please indicate what measures you think should be taken.

    1. ____.
    2. ____.
    3. ____.

SITE ____.

1. Location (e.g. 5 km west Guyra on Inverell road).
   ______________________________.

2. Distance from Armidale ____ miles/km.

3. Please show the proportion of each species cut from 1988 to 1991 using the following table.

	1988	1989	1990	1991
stringybark	______	______	______	______
yellow box	______	______	______	______
white box	______	______	______	______
ironbark	______	______	______	______
red gum	______	______	______	______
white gum	______	______	______	______
________	______	______	______	______

4. Do you have exclusive access to this timber?
   ❐ yes ❐ no

5. Are you charged to extract the timber?
   ❐ yes ❐ no

   If *yes*, what is the rate charged? _____.

6. How long will timber be available from this site? ______ years.

7. Please indicate the source of trees at the site?
   (use percentages for the relevant categories)
   %
   ___ live trees (dried before sale)
   ___ dieback trees
   ___ ringbarked/poisoned trees
   ___ forestry operation residues
   ___ fallen dead timber
   ___ other (please specify) __________.

8. What is the land tenure?
   ❐ freehold (your own property)
   ❐ freehold (other property)
   ❐ leasehold
   ❐ State Forest
   ❐ other crown lands (eg. timber reserve)

APPENDIX V. Landholder telephone survey

i. Survey form

1. Do you use firewood for heating, cooking or water heating?
   (*if no, goto 5*)
2. If yes, how many tonnes on average do you burn each year?
3. Is the firewood cut from the property?
   (*if no, goto 5*)
4. If yes, which species are burnt?
5. Is firewood cut from the property to sell elsewhere?
   (*if no, goto 8*)
6. If yes, what is the average tonnage of firewood cut each year from your property for use elsewhere?
7. Which species?
8. Is timber cut from your property for your own fencing needs around the property?
   (*if no, goto 11*)
9. If yes, what is the average number of trees cut each year for on-farm fencing?
10. Which species?
11. Is timber cut from your property to provide fencing timber or sawlogs elsewhere?
    (*if no, goto 14*)
12. If yes, what is the average number of stems cut each year for use elsewhere?
13. Which species?
14. What is the area of your property (ac/ha)?
15. What percentage of your property remains uncleared?
    (ie. remains covered with native forest or woodland)
16. Which are the 3 most common **native** tree species on your property?
    (list in descending order of abundance)
17. Estimate the number of dead standing trees on your property.
18. How many timber stockyards on your property?
19. How many steel stockyard on your property?

ii. Data input sheet

Landholder Name: ____________________ Date: __________.
Telephone Number: ___________.
Property Name: ______________.

1. ________.

2. ________ tonnes/year

3. ________.

4. ______________________________________.
______________________________________.

5. ________.

6. ________ tonnes/year

7. ______________________________________.
______________________________________.

8. ________.

9. ________ tonnes/year

10. ______________________________________.
______________________________________.

11. ________.

12. ________ tonnes/year

13. ______________________________________.
______________________________________.

14. _______ ac/ha

15. _______ % (= _____ ac/ha)

16.i.__________________ ii. __________________ iii. __________________.

17. _______ dead trees

18. _______ timber stock yards

19. _______ steel stock yards

Appendix VI. Impromptu comments offered by rural landholders during telephone interview (frequency of comment (/235) in parentheses)

Firewood

- clean and pile wood for later use (2)
- wood on my property services two suppliers and 24 private collectors (1)
- lots of dead fallen timber on my property (3)
- like to clean up my dead timber by getting someone to take it (1)
- I have 1000 acres (6 paddocks) of dead trees (1)
- there are 300 acres of ringbarked trees on the property (1)
- estimate 1% of trees on my property are dead (1)
- I estimate 1 dead tree per acre on the property (1)
- there are more dead trees than alive on this property (1)
- I have hundreds of dead trees (14)
- I have thousands of dead trees (27)
- lots of near-dead trees (1)

- collect what's nearest for my own use (1)
- use the heads of trees felled for other purposes (1)
- use only dieback trees for my own firewood (2)
- leave dead trees standing for firewood (1)
- use mainly fallen dead trees for my own use (12)
- use mostly dead trees for my own firewood (6)
- use windfall trees for my firewood (1)
- only burn 'rubbish' timber (1)
- preserve my ironbark for fencing, not firewood (1)
- preserve my stringybark for fencing, not firewood (3)
- use old cattleyard and fencing timber for firewood (4)

- 200 acres on the property have been 'wrung out' (1)
- all my dead trees have been used up (1)
- not many dead trees left (3)
- should be more use of forestry operation residues (1)
- used to supply a small amount to Rotary (1)
- used to supply firewood once (2)

- blue gum is very good and burns hot (1)
- box burns very hot and is the best (3)
- red gum, yellow box and white box all very good (1)
- stringybark easy to split, burns quickly, and 'townies' like it (1)

- provide to a church in Guyra (1)
- give away firewood to friends and relatives (11)
- casual employees take some firewood (1)
- people take only dead fallen timber (1)
- no heat in 'light' species (2)
- peppermint no good (1)

<u>Other</u>

- have dieback on my property (38)
- only scattered trees or isolated clumps remain on property (29)
- little natural regeneration on the property (3)
- stringybark regenerates on unimproved pasture only (1)

- much clearing and ringbarking/poisoning in previous years (22)
- have poisoned and pushed over and burnt thousands of tonnes a year - the merchants want it free but no way ! (1)
- dead timber pushed up - no one will pay royalties so I will burn it (1)
- much poisoning in area west of Guyra still going on (1)
- lots of timber previously removed (9)
- have pushed alot of stringybark over (2)
- I burn fallen timber in the paddock (5)
- fallen dead trees 'tidied' (1)
- ugly old trees 'tidied up' (1)
- piled and burnt many trees which fell during a local storm (1)
- have dozed and burnt much dieback timber (1)
- have cleared many trees (3)
- tordoned about 100 acres of 'close to virgin' bush 4 years ago (1)
- 15 acres ringbarked recently (1)
- regrowth trees need 'hitting' again (1)
- poison suckers (1)
- fell dead timber because of windfall danger (2)

- no part of property totally cleared (4)
- heavily timbered property (3)
- a few good stands on the property (1)

- problems with timber availability (16)
- hardly any living trees remaining (3)
- little box remaining (3)
- yellow box cut out (2)
- red gum 'wrung' out (1)
- entire property was cut out (1)
- only scattered trees remain on the property (15)
- have only isolated clumps of trees (14)

- I recently commenced a sawmill operation at 100 tonnes of stringybark a year (1)
- 300-400 stringybark logs cut 7 year ago (1)
- we had a once off extraction of sawlogs in the last 15 years (1)
- the previous owners logged about 20 years ago (1)
- previous owners logged 20 000 or more trees between 1966 and 1973 (1)
- stopped milling logs 15 years ago and sleepers 10 years ago (1)
- send timber to mills as it matures (2)
- some sawlogs from a bad storm (1)
- land too steep to mill (1)
- gorges very timbered (1)
- rock hills contain alot of the property's timber (14)
- gullies contain alot of the property's timber (3)
- all millable timber was extracted 20 years ago (1)
- regrowth meets all on-farm needs (1)

- fell only one stem of 'twin' trees (1)
- fence off timber to maintain shade and aesthetics (1)
- have fenced for regeneration (4)
- some regrowth on the property (18)
- have wattles on the property (20)
- cleared land now timbered (1)
- we have shelterbelts (10)
- have planted lots of trees (5)
- want koalas re-established (1)
- like to keep dead standing trees for wildlife habitat (3)
- dead trees are good for nutrient recycling (1)
- we collect ironbark seed (1)
- like to preserve box (1)
- want to preserve some trees (1)
- want to conserve what's left (1)

Appendix VII. Expressions used to calculate green-weight, air-dry weight and volume from individual classes of each sampled *E. laevopinea* and *E. melliodora* tree.

Green-weight (kg)

$$
\begin{aligned}
Wt(tree) &= Wt(t) + Wt(b) \\
&= Wt(t)_{stemwood} + Wt(t)_{branchwood} + Wt(b)_{stemwood} + Wt(b)_{branchwood} \\
&= \sum_{dc=1}^{n} (Wt(t))_n + \sum_{dc=1}^{n} (Wt(b))_n
\end{aligned}
$$

Air-dry weight (kg)

$$
\begin{aligned}
DWt(tree) &= DWt(t) + DWt(b) \\
&= DWt(t)_{stemwood} + DWt(t)_{branchwood} + DWt(b)_{stemwood} + DWt(b)_{branchwood} \\
&\quad + Wt(t)_{d.\ stemwood} + Wt(t)_{d.\ branchwood} \\
&= \sum_{dc=1}^{n} (DWt(t))_n + \sum_{dc=1}^{n} (DWt(b))_n + \sum_{dc=1}^{n} (Wt_d)_n
\end{aligned}
$$

Volume (m^3)

$$
\begin{aligned}
V(tree) &= V(t) + V(b) \\
&= V(t)_{stemwood} + V(t)_{branchwood} + V(b)_{stemwood} + V(b)_{branchwood} \\
&\quad + V(t)_{d.\ stemwood} + V(t)_{d.\ branchwood} \\
&= \sum_{dc=1}^{n} (V(t))_n + \sum_{dc=1}^{n} (V(b))_n \sum_{dc=1}^{n} (V(t)_d)_n
\end{aligned}
$$

$Wt(tree)$	= green weight of tree (kg)
$Wt\ (t)$	= green weight of timber (kg)
Wt_d	= weight of deadwood (kg)
$Wt\ (b)$	= green weight of bark (kg)
$Wt\ (t)_{stemwood}$	= green weight of timber in main stem (kg)
$Wt(t)_{d.stemwood}$	= weight of deadwood in main stem (kg)
$Wt\ (t)_{branchwood}$	= green weight of timber in branches (kg)
$Wt(t)_{d.\ branchwood}$	= weight of deadwood in branches (kg)
$Wt\ (b)_{stemwood}$	= green weight of bark in main stem (kg)
$Wt\ (b)_{branchwood}$	= green weight of bark in branches (kg)
$DWt(tree)$	= air-dry weight of tree (kg)
$DWt\ (t)$	= air-dry weight of timber (kg)
$DWt\ (b)$	= air-dry weight of bark (kg)
$DWt\ (t)_{stemwood}$	= air-dry weight of timber in main stem (kg)
$DWt\ (t)_{branchwood}$	= air-dry weight of timber in branches (kg)
$DWt\ (b)_{stemwood}$	= air-dry weight of bark in main stem (kg)
$DWt\ (b)_{branchwood}$	= air-dry weight of bark in branches (kg)
$V(tree)$	= volume of tree (m^3)
$V\ (t)$	= volume of green timber (m^3)
$V\ (t)_d$	= volume of deadwood (m^3)
$V\ (b)$	= volume of bark (m^3)
$V\ (t)_{stemwood}$	= volume of green timber in main stem (m^3)
$V\ (t)_{d\ stemwood}$	= volume of deadwood in main stem (m^3)
$V\ (t)_{branchwood}$	= volume of green timber in branches (m^3)
$V\ (t)_{d\ branchwood}$	= volume of deadwood in branches (m^3)
$V\ (b)_{stemwood}$	= volume of bark in main stem (m^3)
$V\ (b)_{branchwood}$	= volume of bark in branches (m^3)
dc	= diameter class
n	= number of diameter classes (dc) in tree

Appendix VIII. Expressions used to calculate green and air-dry density of each sampled *E. laevopinea* and *E. melliodora* tree.

$$GD(t) = \frac{Wt(t)}{1000 \cdot \left(V(t) - \left(V(t)_{d.\,stemwood} + V(t)_{d.\,branchwood}\right)\right)}$$

$$GD(b) = \frac{Wt(b)}{V(b)}$$

$$DD(t) = \frac{DWt(t)}{V(t)}$$

$$DD(b) = \frac{DWt(b)}{V(b)}$$

$$GD(tree) = \frac{Wt(tree)}{1000 \cdot \left(V(tree) - \left(V(t)_{d.\,stemwood} + V(t)_{d\,branchwood}\right)\right)}$$

$$DD(tree) = \frac{DWt(tree)}{V(tree)}$$

where
GD(t) = green density of timber ($g.cm^{-3}$)
GD(b) = green density of bark ($g.cm^{-3}$)
DD(t) = air-dry density of timber ($g.cm^{-3}$)
DD(b) = air-dry density of bark ($g.cm^{-3}$)
GD(tree) = green density of tree ($g.cm^{-3}$)
DD(tree) = air-dry density of tree ($g.cm^{-3}$)

Appendix IX. Number of trees sampled for DBH and HT in each species in each site-quality class.

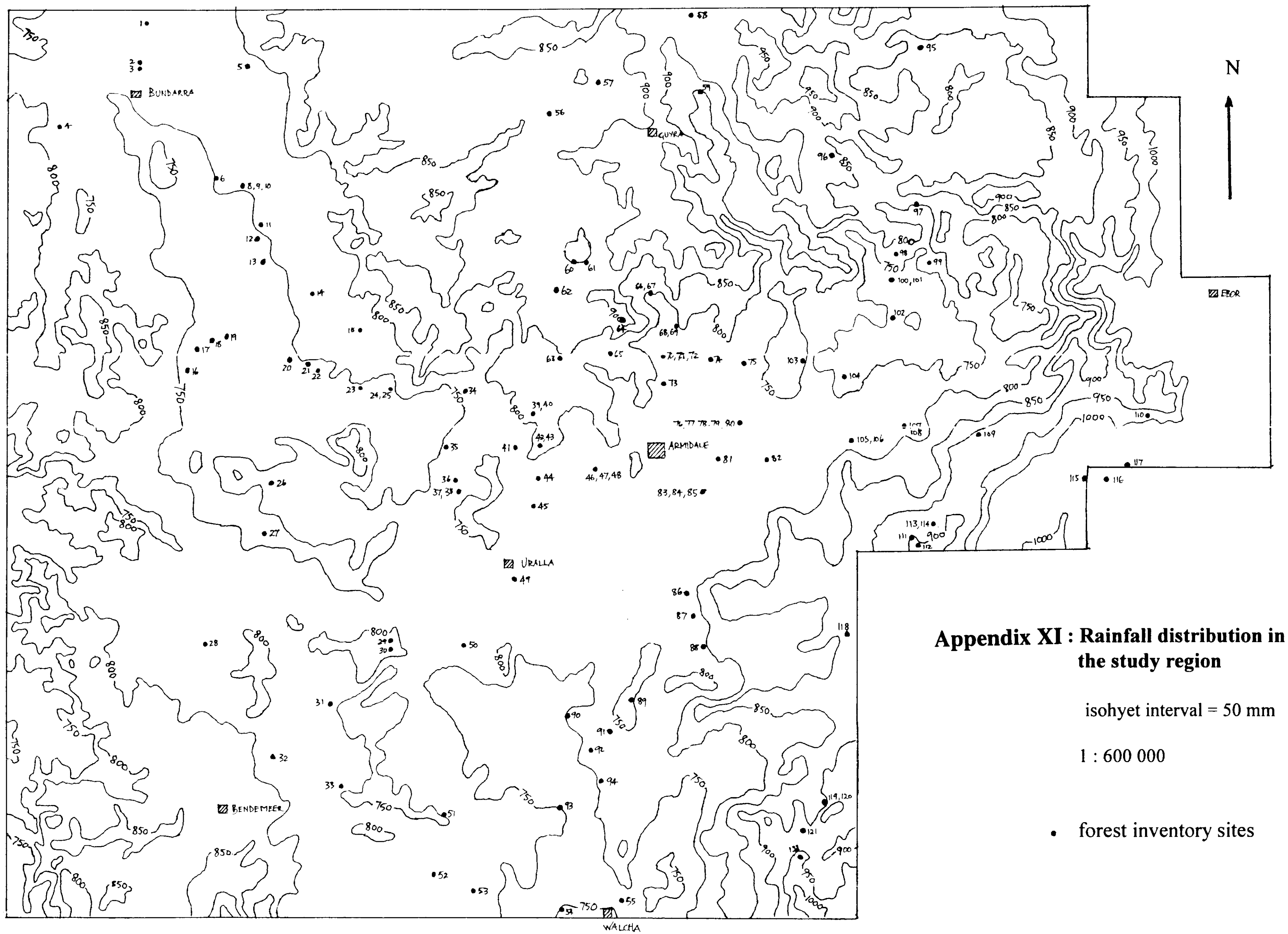
	SQ-1		SQ-2		SQ-3		SQ-4		SQ-5		SQ-6		SQ-7	
TREE*	N	Site No.	N	Site No.	N	Site No.	N	Site No.	N	Site No.	N	Site No.	N	Site No.
GB	-		-		-		-		-		16	1,2,6	44	7,12,21,104
IB	-		-		-		-		-		129	2,3,5,8,9,10,11	89	13,16,17,18, 19,20
RG	-		-		-		-		15	39,40,65	182	1,6,14,15,28,31,32, 34,35,37,38,46,47, 48,49,66,67,68,69, 70.72.74.75.76.77. 78,81,82,83,84,85, 86,88,105,107,108	70	7,12,22,23, 24,25,51,55, 89,102
SB	43	115,116,117	18	110,122	17	109,121	74	60,61,118, 119,120	63	63,65	345	2,3,5,8,9,10,11,28, 31,32,33,34,35,66, 67,69,74,75,76,77, 78,79,80,82,83,84, 85,87,98,99,105, 106,108	94	7,13,16,18, 19,20,51,100, 101,102,103, 104
YB	-		-		18	109	-		37	39,40,63,65	192	1,5,6,14,31,32,34, 35,38,48,50,66,67, 68,69,74,75,77,78, 79,80,82,83,85,87, 88,99,105,106,108	26	12,16,18,22, 25,100,102, 103,104
Totals	43		18		35		74		115		864		323	

* GB = grey box; IB = ironbark; RG = red gum; SB = stringybark; YB = yellow box

Appendix X. Number of trees sampled for DBH, HT and CNVOL in each species in each site-quality class.

	SQ-1		SQ-2		SQ-3		SQ-4		SQ-5		SQ-6		SQ-7	
TREE*	N	Site No.	N	Site No.	N	Site No.	N	Site No.	N	Site No.	N	Site No.	N	Site No.
GB	-		-		-		-		-		1	6	13	7,12,21,104
IB	-		-		-		-		-		121	2,3,5,8,9,10,11	88	13,16,17,18, 19,20
RG	-		-		-		-		3	40,65	81	1,6,14,15,28,31,32, 35,38,46,47,48,49, 68,69,72,74,75,76, 78,81,82,84,85,88, 105,107,108	19	12,22,23,24, 25,51,55,102
SB	43	115,116,117	16	110,122	16	109,121	74	60,61,118, 119,120	52	63,65	239	2,3,5,8,9,10,11,28, 33,34,66,67,69,74, 75,76,77,78,79,80, 83,84,85,87,98,99, 105,106,108	79	7,13,16,18, 19,20,51,100, 101,102,103, 104
YB	-		-		3	109	-		21	39,40,63,65	92	1,5,6,14,35,38,48, 50,66,67,68,69,74, 75,77,79,80,82,85, 99,105,106	18	12,16,18,22, 25,100,102, 103,104
Totals	43		16		19		74		76		534		217	

* GB = grey box; IB = ironbark; RG = red gum; SB = stringybark; YB = yellow box



Appendix XI : Rainfall distribution in the study region

isohyet interval = 50 mm

1 : 600 000

• forest inventory sites

Appendix XII. Disc attributes

Disc attributes for silvertop stringybark (*E. laevopinea*) - site A.

N	S/B	DC	T.g.wt	B.g.wt	DOB	DUB	T.vol	B. Vol	Tv:Bv	T.od.wt	B.od.wt	T.mc	B.mc	T.dr.wt	B.dr.wt	T.g.ρ	T.d.ρ	B.g.ρ	B.d.ρ
18	1	1	140.7	52.8	6.5	5.4	111.3	50	2.2	78	30.7	44.6	41.9	94.9	37	1.264	0.853	1.056	0.74
19	1	2	1663.1	570.1	20.5	15.2	1531.1	1253.9	1.2	981.6	345	41	39.5	1181.1	413.4	1.086	0.771	0.455	0.33
20	1	3	3921.1	1170.1	27.2	21.2	3462.2	2237.1	1.5	2246.3	705.3	42.7	39.7	2717	845.8	1.133	0.785	0.523	0.378
21	2	1	133.3	46.6	5.6	4.7	90.3	37.9	2.4	71.1	22.2	46.7	52.4	87.1	27.8	1.476	0.965	1.23	0.734
22	1	2	2808.3	977.9	24.6	18.8	2604.8	1855.1	1.4	1541.1	593.3	45.1	39.3	1878.3	710.7	1.078	0.721	0.527	0.383
23	1	1	167.5	50.9	6.5	5.3	108.3	54.6	2	98.2	28	41.4	45	118.3	34.1	1.547	1.092	0.932	0.625
24	1	2	1150.4	312.1	16.6	12.9	1049.7	688.5	1.5	630.9	175	45.2	43.9	768.8	212.5	1.096	0.732	0.453	0.309
25	1	2	1965.3	690.3	23.3	15.9	1764.2	2024.3	0.9	1091.4	438.9	44.5	36.4	1327.1	521.8	1.114	0.752	0.341	0.258
26	2	1	195.5	60.5	6.9	6.1	145.4	40.6	3.6	102.2	25.1	47.7	58.5	125.7	32.4	1.345	0.865	1.49	0.798
27	1	2	1308.8	311.4	17.1	13.9	1141.3	586	1.9	751.2	169.4	42.6	45.6	908.3	206.8	1.147	0.796	0.531	0.353
28	1	2	2774.4	853.4	24.4	17.6	2379.6	2194	1.1	1566.6	512.5	43.5	39.9	1899.8	615	1.166	0.798	0.389	0.28
29	1	1	949.4	319.1	14.4	11.5	838.9	476.4	1.8	559	175.8	41.1	44.9	673	214.1	1.132	0.802	0.67	0.449
30	1	2	1804.5	789.5	21	14.9	1543.1	1522.1	1	1057.3	513.2	41.4	35	1273.9	607.9	1.169	0.826	0.519	0.399
31	1	1	166.5	63.1	7	5.2	107.9	87.6	1.2	96.9	35.3	41.8	44.1	116.9	42.9	1.543	1.083	0.72	0.49
32	1	2	948.4	173.8	17.2	15	785	247.2	3.2	590.5	88.4	37.7	49.1	704.4	109.3	1.208	0.897	0.703	0.442
33	1	3	5125.7	930.6	33.4	29.8	4349.1	1114.3	3.9	3224	593.1	37.1	36.3	3839.1	704.7	1.179	0.883	0.835	0.632
34	1	2	832.3	215.6	16.2	13.3	685.8	331.7	2.1	511.3	114.5	38.6	46.9	611.1	140.4	1.214	0.891	0.65	0.423
35	1	3	3720.8	634.3	31.4	28	3178.7	818.8	3.9	2211.2	326.1	40.6	48.6	2657.4	402.2	1.171	0.836	0.775	0.491
36	1	3	10028.2	1572.3	44.5	39.6	8678.9	2280.7	3.8	6057.4	891.2	39.6	43.3	7260.7	1080	1.155	0.837	0.689	0.474
37	1	1	154.1	60.2	9	7.2	139.4	78.4	1.8	84.4	26.6	45.2	55.8	102.9	33.8	1.105	0.738	0.768	0.431
38	1	2	1173.4	280.2	21.2	17.9	1123.7	452.5	2.5	626.3	136.6	46.6	51.2	767.2	170.3	1.044	0.683	0.619	0.376
39	1	3	3583.5	826.5	32	26.7	3193.7	1393.8	2.3	1815.9	448.2	49.3	45.8	2246.1	547.3	1.122	0.703	0.593	0.393
40	2	1	208.7	73	9.7	8	201.8	94.9	2.1	113.5	35.1	45.6	51.9	138.6	43.9	1.034	0.687	0.769	0.463
41	1	1	180.1	81.3	9.8	7.4	149.8	112.9	1.3	86.8	35.3	51.8	56.6	108.4	45.1	1.202	0.724	0.72	0.399
42	1	1	163	54.9	8.8	6.7	143	103.7	1.4	86.2	32.8	47.1	40.3	105.8	39.4	1.14	0.74	0.529	0.38
43	1	1	244	82.8	10.3	7.8	209.8	156	1.3	140	48.5	42.6	41.4	169.3	58.4	1.163	0.807	0.531	0.374
44	1	1	63.7	39.7	6.7	4.7	58.2	60.1	1	31.1	17.4	51.2	56.2	38.7	22.2	1.095	0.665	0.661	0.369
45	1	1	96.7	50.1	7.2	5	88.3	94.8	0.9	53	27.7	45.2	44.7	64.6	33.7	1.095	0.732	0.528	0.355
46	1	1	293.7	91	10.4	8.2	250.4	152.4	1.6	147.5	46.9	49.8	48.5	182.7	57.8	1.173	0.73	0.597	0.379
47	1	2	486.1	151.1	15	11.7	408	262.6	1.6	250.9	88.4	48.4	41.5	309.2	106.5	1.191	0.758	0.575	0.406
48	2	1	83.3	31.7	5.7	4.5	75	45.3	1.7	44.3	16.4	46.8	48.3	54.3	20.2	1.111	0.724	0.7	0.446
49	1	1	277.6	84.6	10.1	8.5	240.1	98.9	2.4	122.5	32.9	55.9	61.1	155.8	43.1	1.156	0.649	0.855	0.436
50	1	2	592.9	270.5	15.7	11.5	513.9	443.9	1.2	279.3	113.2	52.9	58.2	350.4	145.6	1.154	0.682	0.609	0.328
51	2	1	38.4	33	5.5	3.3	29.6	52.6	0.6	19.5	15.6	49.2	52.7	24.1	19.6	1.297	0.814	0.627	0.373
52	1	1	247.1	72.6	10	8.6	231.4	81.5	2.8	135	36.3	45.4	50	164.6	45	1.068	0.711	0.891	0.552
53	1	2	1334.7	261.3	21	18.7	1325.5	346.1	3.8	738.2	144.3	44.7	44.8	898.3	175.6	1.007	0.678	0.755	0.507
54	1	3	3208	608.6	29.5	25.4	2887.7	1007.5	2.9	1752.1	338.7	45.4	44.3	2136.9	411.8	1.111	0.74	0.604	0.409
55	2	2	809	215.7	16.8	14.2	742.3	296.7	2.5	446	109.7	44.9	49.1	543	135.6	1.09	0.732	0.727	0.457
56	2	1	208.9	60.6	9.8	8.4	198.1	71.5	2.8	114.5	28.5	45.2	53	139.6	35.8	1.055	0.705	0.848	0.501
57	1	1	199.5	66.2	11	8.2	189	151.1	1.3	109.2	31.5	45.3	52.4	133.1	39.4	1.056	0.704	0.438	0.261
58	1	2	867.1	221.3	18.1	14.3	759.4	457.2	1.7	453.4	119	47.7	46.2	557.5	145.6	1.142	0.734	0.484	0.318
59	1	3	3187.8	700	30.8	24	2687.4	1738.6	1.5	1613.7	408.3	49.4	41.7	1996.1	492.2	1.186	0.743	0.403	0.283
60	2	1	316	98.4	12.1	8.9	283	240.1	1.2	163.8	53.9	48.2	45.2	201.7	65.7	1.117	0.713	0.41	0.274
61	1	1	422.1	120.3	12.8	11	398.5	141.1	2.8	263.2	65.9	37.6	45.2	313.9	80.3	1.059	0.788	0.853	0.569
62	1	2	2019.2	325	23.5	21.3	1863.3	404.8	4.6	1199.5	186	40.6	42.8	1441.8	225	1.084	0.774	0.803	0.556
63	1	3	2914.8	536.8	34.2	30.8	2590.3	603.4	4.3	1669.6	335.2	42.7	37.6	2019.5	399.5	1.125	0.78	0.89	0.662
64	2	1	330.8	96.3	10.6	9.1	284.1	101.4	2.8	192.9	50.7	41.7	47.4	232.6	62.2	1.164	0.819	0.95	0.613
65	2	2	795.7	142.3	19.5	17.7	863.9	184.6	4.7	473.7	87.8	40.5	38.3	569.1	104.9	0.921	0.659	0.771	0.568
66	1	1	244.8	91.4	10.3	7.5	211.9	187.8	1.1	135.7	48.7	44.6	46.7	165.1	59.7	1.155	0.779	0.487	0.318
67	1	2	380.3	167.2	14.9	10.5	335.6	340.2	1	209.6	101.2	44.9	39.5	255.2	121.3	1.133	0.76	0.491	0.357
68	2	1	62.2	23.8	5.1	4.1	52.2	28.6	1.8	35.1	11.9	43.6	50	42.6	14.8	1.192	0.816	0.832	0.517
69	1	1	244.3	74.6	9.8	8.1	220.6	102.3	2.2	147.2	44.7	39.7	40.1	176.6	53.6	1.107	0.801	0.729	0.524
70	1	2	1479.4	382.9	22.8	19	1283.5	564.7	2.3	889.5	247	39.9	35.5	1066.9	292.9	1.153	0.831	0.678	0.519
71	1	3	3052.1	876.8	32.3	25.8	2660.4	1509.4	1.8	1775.9	599.8	41.8	31.6	2142.3	705	1.147	0.805	0.581	0.467
72	2	1	358.5	125.1	11.2	8.7	315	207	1.5	202.7	66.1	43.5	47.2	245.7	81.1	1.138	0.78	0.604	0.392
73	2	2	802.8	252.2	16.4	12.5	609.6	439.7	1.4	473.7	154.5	41	38.7	570	184.8	1.317	0.935	0.574	0.42
74	1	1	482.3	136.9	10.9	8.8	435.6	232.7	1.9	277.3	66.8	42.5	51.2	335.2	83.2	1.107	0.77	0.588	0.358
75	1	2	1012	271.1	18.7	14.7	862	532.9	1.6	589.5	152.4	41.7	43.8	711.1	184.9	1.174	0.825	0.509	0.347
76	1	3	4018	808.4	42	34.3	3886.8	1941	2	2397.5	512.9	40.3	36.6	2880	609.8	1.034	0.741	0.416	0.314
77	1	4	5787.2	1119.7	47	40.5	5010.3	1737.3	2.9	3449.6	733.3	40.4	34.5	4143.9	867.7	1.155	0.827	0.645	0.499
78	2	1	339.2	99.1	11.7	9.2	296.8	183.2	1.6	197.3	50.3	41.8	49.2	238	62.2	1.143	0.802	0.541	0.34
79	2	2	1700	451.6	22.5	17	1449.9	1089.9	1.3	1009.2	268.6	40.6	40.5	1213.4	322.8	1.172	0.837	0.414	0.296
80	2	3	2106	545.7	24.5	18.5	1761.9	1328.2	1.3	1273.2	334.7	39.5	38.7	1526.2	400.1	1.195	0.866	0.411	0.301
81	1	1	294.5	82.7	10.2	8.4	272.3	129.2	2.1	166.6	43.1	43.4	47.9	202	53	1.082	0.742	0.64	0.41
82	1	2	837.7	242.6	19	14.9	707.4	442.9	1.6	478.3	132.1	42.9	45.5	578.8	161.2	1.184	0.818	0.548	0.364
83	2	1	220.2	66.7	9.7	7.7	189.3	111.1	1.7	123.8	34.5	43.8	48.3	150.2	42.5	1.163	0.793	0.6	0.383
84	2	1	82.9	30.5	5.3	4.3	73.4	38.1	1.9	41.5	12.7	49.9	58.4	51.5	16.4	1.129	0.702	0.801	0.43

Disc attributes for yellow box (*E. melliodora*) - site A.

N	S/B	DC	T.g.wt	B.g.wt	DOB	DUB	T.vol	B. Vol	Tv:Bv	T.od.wt	B.od.wt	T.mc	B.mc	T.dr.wt	B.dr.wt	T.g.ρ	T.d.ρ	B.g.ρ	B.d.ρ
1	1	1	462.1	101.9	11.5	10.1	383.2	113.6	3.4	309.3	48.6	33.1	52.3	364.7	60.8	1.206	0.952	0.897	0.535
2	1	2	1109.2	172.9	19.9	17.3	900.5	291	3.1	731.3	84.1	34.1	51.4	864.3	104.8	1.232	0.96	0.594	0.36
3	1	3	3547.1	445.2	32.3	30	2760.1	439.4	6.3	2307.3	212.2	35	52.3	2732.4	265.7	1.285	0.99	1.013	0.605
4	2	1	288	71.6	10.1	8.6	234.4	88.9	2.6	189.5	34.6	34.2	51.7	224.1	43.2	1.229	0.956	0.805	0.486
5	2	2	953.3	162.2	17.1	15.7	772.3	143.9	5.4	638	75.2	33.1	53.6	752.3	94.7	1.234	0.974	1.127	0.658
6	1	1	295.5	111.2	9.5	8.1	240.7	90.4	2.7	188.7	53.6	36.1	51.8	224.2	66.9	1.228	0.931	1.23	0.74
7	1	2	1075.8	407.2	17.7	14.5	846.9	415.1	2	714.7	207.4	33.6	49.1	843.7	256.2	1.27	0.996	0.981	0.617
8	2	1	177.9	39.3	7.2	6.5	145.8	33.1	4.4	123.3	18.6	30.7	52.7	144.6	23.3	1.22	0.992	1.187	0.704
9	1	1	392.7	129.6	11.9	10.1	334.9	130	2.6	240	51.3	38.9	60.4	287.1	66.9	1.173	0.857	0.997	0.515
10	1	2	799.2	279.3	16	13.3	680	304.1	2.2	511.1	120.9	36	56.7	607.1	154.4	1.175	0.893	0.918	0.508
11	2	1	97.8	39.3	6.8	5.5	84.3	44.6	1.9	61.4	16.1	37.2	59	73.1	20.8	1.16	0.867	0.881	0.466
12	1	1	623.4	127.6	13	11.9	502.1	97.1	5.2	407.5	54.2	34.6	57.5	482.4	69.5	1.242	0.961	1.314	0.716
13	1	2	1377.5	192.9	21.6	20	1113.5	185.3	6	928.6	81.4	32.6	57.8	1093.8	104.5	1.237	0.982	1.041	0.564
14	1	4	15750.6	1250.8	52.5	50	12245.6	1255.2	9.8	10333.7	606.4	34.4	51.5	12223.3	756.6	1.286	0.998	0.996	0.603
15	2	1	323.5	71.2	9.7	8.7	256	62.2	4.1	216.6	31.4	33	55.9	255.5	39.9	1.264	0.998	1.145	0.641
16	2	2	1326.5	197.3	19.5	18	1060.6	184.1	5.8	868.5	79.7	34.5	59.6	1027.8	103.4	1.251	0.969	1.072	0.562
17	2	3	2267.3	263.5	28	25.7	1821.8	340.7	5.3	1538.3	122.8	32.2	53.4	1810	154.4	1.245	0.994	0.773	0.453
18	1	1	451.7	74.6	12.3	11.2	357.6	73.7	4.9	302.2	30.4	33.1	59.2	356.4	39.4	1.263	0.997	1.012	0.535
19	1	2	1342.8	216.9	20.1	18.4	1093.2	211.3	5.2	896.4	88.8	33.2	59.1	1057.7	114.8	1.228	0.968	1.027	0.543
20	1	3	7302.1	887.2	38.7	35.9	5704.1	924.5	6.2	4871.4	365.3	33.3	58.8	5747.3	471.8	1.28	1.008	0.96	0.51
21	2	3	2938.8	426.5	26.9	24.9	2348.8	392.5	6	1960.2	173.6	33.3	59.3	2312.8	224.8	1.251	0.985	1.087	0.573
22	2	2	936.9	141.5	16.1	14.8	740.1	135.7	5.5	641.9	52.2	31.5	63.1	754.3	69.2	1.266	1.019	1.043	0.51
23	2	1	409.9	83.4	11.5	10.2	334.2	90.6	3.7	276.7	33.4	32.5	60	325.9	43.4	1.227	0.975	0.921	0.479
24	1	3	6868.6	1161.5	35.7	32.8	5431.7	1002.9	5.4	4394.3	560.7	36	51.7	5219.1	700.2	1.265	0.961	1.158	0.698
25	1	2	2466.8	411.7	22.9	20.9	1989.4	399	5	1599.1	189.8	35.2	53.9	1894.9	239.2	1.24	0.952	1.032	0.599
26	1	1	451.8	115.9	12.5	10.9	384.9	121.3	3.2	288.1	49.6	36.2	57.2	342.4	63.5	1.174	0.89	0.955	0.523
27	2	2	1497.8	273.9	19.7	18	1226.2	242.6	5.1	960.2	124.6	35.9	54.5	1139.9	157.5	1.221	0.93	1.129	0.649
28	2	1	209.4	48.8	9.1	8	176.1	51.8	3.4	132.9	20.4	36.5	58.2	158.1	26.3	1.189	0.898	0.942	0.508
29	1	1	234.1	58.5	9.5	8.1	195.3	73.3	2.7	152.6	27.2	34.8	53.5	180.7	34.2	1.199	0.925	0.798	0.467
30	1	1	518.9	151.4	13.2	11.3	434.5	158.4	2.7	315.8	60.6	39.1	60	378.1	78.8	1.194	0.87	0.956	0.497
31	1	2	991.6	300.8	17	14.1	867.5	393.5	2.2	608.3	132.2	38.7	56.1	727.2	168.3	1.143	0.838	0.764	0.428
32	2	1	63.5	23	5.5	4.6	53.2	22.9	2.3	38.9	10.3	38.7	55.2	46.5	13.1	1.194	0.874	1.004	0.572
33	1	1	304.7	58.8	9.8	8.6	249.9	74.6	3.3	206.9	26.5	32.1	54.9	243.5	33.6	1.219	0.974	0.788	0.45
34	1	2	1738.9	286.3	22.1	20.2	1295.7	255.2	5.1	1151.7	130.5	33.8	54.4	1360.2	164.9	1.342	1.05	1.122	0.646
35	1	3	3279.8	571.7	29.6	26.8	2579.6	567.2	4.5	2166.3	259	34	54.7	2559.3	327.6	1.271	0.992	1.008	0.578
36	2	1	524.7	95	12.6	11.3	417.6	101.6	4.1	351.4	42.4	33	55.4	414.4	53.8	1.256	0.992	0.935	0.53
37	2	2	761.6	133.3	15.4	14.2	609.1	107.3	5.7	521.6	58	31.5	56.5	613	74	1.25	1.006	1.242	0.69
38	1	1	338.7	77.3	10.2	9.1	275	70.5	3.9	215.2	34.2	36.5	55.8	255.8	43.5	1.232	0.93	1.096	0.617
39	1	3	2999.6	632.4	26.3	23.2	2400.7	684.4	3.5	2013	293.6	32.9	53.6	2372.9	369.5	1.249	0.988	0.924	0.54
40	1	2	1257.6	218.1	18.3	16.7	1023.9	205.6	5	801.4	92.1	36.3	57.8	952.2	118.3	1.228	0.93	1.061	0.575
41	2	1	272.8	59	10.2	9	225.4	64.1	3.5	173.7	25.9	36.3	56.1	206.5	33	1.21	0.916	0.92	0.515
42	1	1	677.5	130.3	14	12.4	533.1	146.4	3.6	447.3	61.3	34	53	528.5	76.9	1.271	0.991	0.89	0.525
43	1	2	1948.3	367.9	22.9	20.3	1557.3	424.5	3.7	1297.5	152.9	33.4	58.4	1531.3	197.1	1.251	0.983	0.867	0.464
44	1	3	2919.7	897.8	27	23.3	2378.6	815.4	2.9	1924.5	408.8	34.1	54.5	2274.7	516.5	1.227	0.956	1.101	0.633
45	2	1	308.1	74.1	9.8	8.7	248.5	66.8	3.7	204.5	32.7	33.6	55.9	241.5	41.6	1.24	0.972	1.109	0.623
46	2	2	1355.2	268.8	17.3	15.5	1079.9	265.4	4.1	908.2	112.1	33	58.3	1070.7	144.4	1.255	0.991	1.013	0.544

Disc attributes for New England stringybark (*E.caliginosa*) - site B.

N	DC	T.g.wt	B.g.wt	DOB	DUB	T.vol	B. Vol	Tv:Bv	T.od.wt	B.od.wt	T.mc	B.mc	T.dr.wt	B.dr.wt	T.g.ρ	T.d.ρ	B.g.ρ	B.d.ρ
1	1	74.5	42.3	6.7	4.2	71.1	109.8	0.6	40	26	46.3	38.5	48.9	31.1	1.048	0.688	0.385	0.283
2	1	459.4	166.9	14.5	11	465.6	343.4	1.4	262.7	108.4	42.8	35.1	317.8	128.4	0.987	0.683	0.486	0.374
3	1	94.6	40.9	7	5.3	89.4	66.5	1.3	47.4	19.6	49.9	52.1	58.8	24.5	1.058	0.658	0.615	0.368
4	2	1217.9	442.4	18.2	13.2	1096.3	987.8	1.1	629.5	279.6	48.3	36.8	775.7	332.7	1.111	0.708	0.448	0.337
5	1	48.7	17.8	5.1	4.1	43	23.5	1.8	24.9	8.6	48.9	51.7	30.7	10.7	1.133	0.714	0.757	0.455
6	1	251.2	82.9	10.8	8.3	223	154.6	1.4	139.1	44.8	44.6	46	169.3	54.7	1.126	0.759	0.536	0.354
7	3	3291.3	655.5	30.8	25.7	2277.8	993.7	2.3	1766.7	398.5	46.3	39.2	2161.8	477.2	1.445	0.949	0.66	0.48
8	2	976.1	288.5	18	13.5	860.6	669.4	1.3	542.6	170.7	44.4	40.8	659.8	205.3	1.134	0.767	0.431	0.307
9	2	2542.1	758.1	24.1	18	1775.8	1407.5	1.3	1477.2	487.6	41.9	35.7	1782.2	578.5	1.432	1.004	0.539	0.411
10	1	202.7	79.9	9.7	7	213.3	196.3	1.1	120.6	49.2	40.5	38.4	144.9	58.8	0.95	0.679	0.407	0.3
11	2	752.5	299.3	16.6	11.8	660.3	646.5	1	428.7	198.2	43	33.8	519.1	234.1	1.14	0.786	0.463	0.362
12	1	86.4	35.1	6.8	4.9	81	75	1.1	45.4	21.1	47.5	39.9	55.8	25.3	1.067	0.689	0.468	0.337
13	1	391.1	145.2	11.5	8.9	398	266.5	1.5	212.7	85.8	45.6	40.9	259.6	103.2	0.983	0.652	0.545	0.387
14	1	75	29.4	5.4	4.1	64	47	1.4	39.6	17.4	47.2	40.8	48.6	20.9	1.172	0.759	0.626	0.445
15	2	1068	333	20.5	15	910.6	790.2	1.2	571.2	204.1	46.5	38.7	699.4	244.1	1.173	0.768	0.421	0.309
16	1	113.9	52.6	7	5.5	88.9	55.1	1.6	61.3	28.7	46.2	45.4	75	35	1.281	0.844	0.955	0.635
17	2	828.7	334	20.2	13.6	688.6	830.5	0.8	481.8	223.7	41.9	33	581.2	263.8	1.203	0.844	0.402	0.318
85	1	77.5	41.5	6	4	87.4	109.3	0.8	39	22.8	49.7	45.1	48.3	27.8	0.887	0.553	0.38	0.254
86	2	529.1	240.2	15.5	11.5	412.3	336.7	1.2	304.1	157.5	42.5	34.4	367.6	186.3	1.283	0.892	0.713	0.553

Notation

N	= sample disc number
S/B	= stem/branch class (1= stem; 2 = branch)
DC	= diameter class (1= 5-15; 2 = 15-25; 3 = 25-45; 4 = 45-65 cm)
T.g.wt	= timber green weight (g)
B.g.wt	= bark green weight (g)
DOB	= diameter over bark (cm)
DUB	= diameter under bark (cm)
T.vol	= volume of timber (cm^3)
B.vol	= volume of bark (cm^3)
Tv:Bv	= timber to bark volume ratio
T.od.wt	= timber oven dry weight (g)
B.od.wt	= bark oven dry weight (g)
T.mc	= timber moisture content (% g.wt)
B.mc	= bark moisture content (% g.wt)
T.d.wt	= timber air-dry weight (g)
B.d.wt	= bark air-dry weight (g)
T.g.ρ	= timber green density (g/cm^3)
T.d.ρ	= timber air-dry density (g/cm^3)
B.g.ρ	= bark green density (g/cm^3)
B.d.ρ	= bark air-dry density (g/cm^3)

Appendix XIII. Tree mensuration data for green trees

i. E. caliginosa (site B; 21 trees)

Ht	DBH	CnVol	1st brnch	G.wt.t	G.wt.b	D.wt.t	D.wt.b	Vol.t	Vol.b	gd.t	gd.b	dd.t	dd.b	G.wt	D.wt	Vol	gd	dd
12	17	88		71.1	27	47.6	19.6	0.064	0.051	1.111	0.529	0.744	0.384	98.1	67.2	0.115	0.853	0.584
13	22	120		124.5	46.5	83.9	34	0.113	0.089	1.102	0.522	0.742	0.382	171	117.9	0.202	0.847	0.584
10	16	12		32.4	12.6	21.6	9	0.029	0.024	1.117	0.525	0.745	0.375	45	30.6	0.053	0.849	0.577
8.5	14	14		32.6	12.4	21.9	9	0.03	0.023	1.087	0.539	0.73	0.391	45	30.9	0.053	0.849	0.583
10	16	19		122.6	45.9	82.5	33.6	0.111	0.088	1.105	0.522	0.743	0.382	168.5	116.1	0.199	0.847	0.583
15	20	81		43.2	16.3	29	11.9	0.039	0.031	1.108	0.526	0.744	0.384	59.5	40.9	0.07	0.85	0.584
14.5	27	111		164.6	51.5	111	37.7	0.132	0.099	1.247	0.52	0.841	0.381	216.1	148.7	0.231	0.935	0.644
13	23.5	135		146.6	49.9	98.9	36.6	0.125	0.096	1.173	0.52	0.791	0.381	196.5	135.5	0.221	0.889	0.613
15.5	29.5	288		404.4	128.4	273	94.4	0.33	0.248	1.225	0.518	0.827	0.381	532.8	367.4	0.578	0.922	0.636
13.5	20.5	12		89	34.8	59.3	24.8	0.081	0.065	1.099	0.535	0.732	0.382	123.8	84.1	0.146	0.848	0.576
12.5	16.5	23		62.9	24.1	42.2	17.4	0.057	0.045	1.104	0.536	0.74	0.387	87	59.6	0.102	0.853	0.584
12.5	18	36		70.1	26.9	47	19.4	0.064	0.051	1.095	0.527	0.734	0.38	97	66.4	0.115	0.843	0.577
12	18	30		73.1	28	48.9	20.2	0.066	0.053	1.108	0.528	0.741	0.381	101.1	69.1	0.119	0.85	0.581
18	46.5	765	4.5	1357.8	323.6	917.2	238.3	1.048	0.625	1.296	0.518	0.875	0.381	1681.4	1155.5	1.673	1.005	0.691
18	23.5	79	11.5	196	63.2	132.6	46.8	0.163	0.123	1.202	0.514	0.813	0.38	259.2	179.4	0.286	0.906	0.627
11.5	18.5	74	6	84.1	31.5	56.6	23	0.076	0.06	1.107	0.525	0.745	0.383	115.6	79.6	0.136	0.85	0.585
16	20	75	7	88.5	33.8	59.3	24.4	0.08	0.064	1.106	0.528	0.741	0.381	122.3	83.7	0.144	0.849	0.581
17.5	20	189	8	127.7	48.1	86	35.1	0.115	0.091	1.11	0.529	0.748	0.386	175.8	121.1	0.206	0.853	0.588
16.5	19.5	121	6	92.1	35	61.8	25.4	0.083	0.066	1.11	0.53	0.745	0.385	127.1	87.2	0.149	0.853	0.585
18.5	22.5	12	15	131.8	48.8	88.9	35.9	0.119	0.094	1.108	0.519	0.747	0.382	180.6	124.8	0.213	0.848	0.586
17	28.5	158	8	276.2	104.1	185.7	75.9	0.251	0.198	1.1	0.526	0.74	0.383	380.3	261.6	0.449	0.847	0.583

ii. E. laevopinea (site A; 31 trees)

Ht	DBH	CnVol	1st brnch	G.wt.t	G.wt.b	D.wt.t	D.wt.b	Vol.t	Vol.b	gd.t	gd.b	dd.t	dd.b	G.wt	D.wt	Vol	gd	dd
15.5	39	714	3.5	557	138	392	93	0.549	0.229	1.045	0.603	0.714	0.406	695	485	0.778	0.912	0.623
8.5	12	41	2.5	24.5	8	16.5	5	0.022	0.012	1.114	0.667	0.75	0.417	32.5	21.5	0.034	0.956	0.632
10	12.5	13	5	22.5	7.5	15	4.5	0.019	0.01	1.184	0.75	0.789	0.45	30	19.5	0.029	1.034	0.672
10.5	13	38	4.5	30	10	20	6	0.029	0.016	1.034	0.625	0.69	0.375	40	26	0.045	0.889	0.578
5.5	7.5	13	1.5	5.5	2	4	1	0.005	0.003	1.1	0.667	0.8	0.333	7.5	5	0.008	0.938	0.625
6.5	8.5	8	4	8	2.5	5.5	1.5	0.008	0.005	1	0.5	0.688	0.3	10.5	7	0.013	0.808	0.538
11.5	16	81	4.5	75.5	23	51	15	0.07	0.037	1.079	0.622	0.729	0.405	98.5	66	0.107	0.921	0.617
10	18	70	1	65	18.5	44	12	0.06	0.032	1.083	0.578	0.733	0.375	83.5	56	0.092	0.908	0.609
16.5	34.5	476	5	613.5	156	420.5	105	0.523	0.237	1.173	0.658	0.804	0.443	769.5	525.5	0.76	1.013	0.691
15.5	32	270	4.5	373.5	96	261	64	0.38	0.166	1.023	0.578	0.687	0.386	469.5	325	0.546	0.884	0.595
10	19.5	120	2	103.5	30.5	75	19.5	0.101	0.05	1.089	0.61	0.743	0.39	134	94.5	0.151	0.924	0.626
18	40.5	578	6	1079.5	264.5	816	181	1.06	0.408	1.133	0.648	0.77	0.444	1344	997	1.468	0.988	0.679
9.5	15.5	63	4	38.5	11.5	26	7.5	0.041	0.022	0.939	0.523	0.634	0.341	50	33.5	0.063	0.794	0.532
13.5	31	186	2	322	93	221.5	60.5	0.326	0.158	1.003	0.589	0.679	0.383	415	282	0.484	0.866	0.583
22	64.5	1875	6	2736	652.5	1908.5	451.5	2.748	1.128	1.008	0.578	0.695	0.4	3388.5	2360	3.876	0.882	0.609
23.5	80	3053	4	5203	1108	3891.5	781.5	5.124	1.896	1.089	0.584	0.759	0.412	6311	4673	7.02	0.946	0.666
18	39	406	3	874.5	222	625	149.5	0.853	0.354	1.08	0.627	0.733	0.422	1096.5	774.5	1.207	0.942	0.642
13.5	34	249	3	372	95.5	280.5	64	0.377	0.157	1.101	0.608	0.744	0.408	467.5	344.5	0.534	0.944	0.645
14.5	19.5	23	7	99.5	28	69.5	18	0.1	0.049	1.036	0.567	0.695	0.364	127.5	87.5	0.149	0.877	0.586
12	27	165	4.5	215	61.5	152.5	40	0.21	0.098	1.08	0.628	0.726	0.408	276.5	192.5	0.308	0.931	0.625
18	39	390	7	870.5	216.5	611.5	147	0.844	0.367	1.071	0.59	0.725	0.401	1087	758.5	1.211	0.921	0.626
18.5	50.5	948	5	1560.5	374.5	1162.5	259.5	1.599	0.607	1.065	0.617	0.727	0.428	1935	1422	2.206	0.934	0.645
13.5	22	117	5.5	134.5	38	91.5	25	0.126	0.065	1.067	0.585	0.726	0.385	172.5	116.5	0.191	0.903	0.61
13	20	188	3	132.5	37	90	24.5	0.121	0.062	1.095	0.597	0.744	0.395	169.5	114.5	0.183	0.926	0.626
16	28	111		315.3	77.7	216.7	53.2	0.277	0.131	1.138	0.593	0.782	0.406	393	269.9	0.408	0.963	0.662
14	20.5	70		140	36.3	96	24.6	0.123	0.062	1.138	0.585	0.78	0.397	176.3	120.6	0.185	0.953	0.652
14	28	135		172.1	42.2	118.2	28.7	0.151	0.068	1.14	0.621	0.783	0.422	214.3	146.9	0.219	0.979	0.671
14.5	23.5	114		163.3	38.7	112.2	26.5	0.143	0.062	1.142	0.624	0.785	0.427	202	138.7	0.205	0.985	0.677
14	20	37		121.3	31.2	83.2	21.2	0.107	0.053	1.134	0.589	0.778	0.4	152.5	104.4	0.16	0.953	0.653
19	39.5	520		881.8	205.1	607.3	141.4	0.771	0.331	1.144	0.62	0.788	0.427	1086.9	748.7	1.102	0.986	0.679
22.5	69	1458		2681.4	577.1	1887.7	421.3	2.332	0.916	1.15	0.63	0.809	0.46	3258.5	2309	3.248	1.003	0.711

iii. *E. melliodora* (site A; 12 trees)

Ht	DBH	CnVol	1st brnch	G.wt.t	G.wt.b	D.wt.t	D.wt.b	Vol.t	Vol.b	gd.t	gd.b	dd.t	dd.b	G.wt	D.wt	Vol	gd	dd
20.5	38.5	748	7.5	1291	234.5	1075.5	133	1.165	0.246	1.199	0.953	0.923	0.541	1525.5	1208.5	1.411	1.153	0.856
10.5	18	138	3	120.5	25.5	94	14.5	0.105	0.027	1.17	0.944	0.895	0.537	146	108.5	0.132	1.123	0.822
11.5	16	125	4.5	94.5	21	73	12	0.081	0.022	1.167	0.955	0.901	0.545	115.5	85	0.103	1.121	0.825
24	63.5	1725	7.5	3894.5	524	3041.5	301	3.292	0.553	1.192	0.948	0.924	0.544	4418.5	3342.5	3.845	1.156	0.869
20.5	44	1045	6.5	2023	374.5	1678	211.5	1.772	0.382	1.228	0.98	0.947	0.554	2397.5	1889.5	2.154	1.182	0.877
19.5	41	827	7	1451	265	1134.5	149.5	1.229	0.278	1.189	0.953	0.923	0.538	1716	1284	1.507	1.146	0.852
19	47	2633	4.5	2247.5	383	1792	217.5	1.884	0.388	1.232	0.987	0.951	0.561	2630.5	2009.5	2.272	1.189	0.884
11	11	17	6	29	7	22.5	4	0.03	0.009	0.967	0.778	0.75	0.444	36	26.5	0.039	0.923	0.679
12	19	104	5	131.5	28	101.5	15.5	0.116	0.03	1.134	0.933	0.875	0.517	159.5	117	0.146	1.092	0.801
19	34.5	1211	2	969.5	188	760.5	106	0.81	0.193	1.212	0.974	0.939	0.549	1157.5	866.5	1.003	1.166	0.864
15.5	25.5	360	4.5	463.5	92	377.5	51.5	0.401	0.098	1.165	0.939	0.941	0.526	555.5	429	0.499	1.12	0.86
17	28.5	544	6	633	125	492.5	70	0.54	0.132	1.177	0.947	0.912	0.53	758	562.5	0.672	1.131	0.837

note: 1st brnch variable was not measured for the majority of *E. caliginosa* and for some *E. laevopinea*

Ht = height (m)
DBH = overbark diameter at breast height (cm)
CnVol = crown volume (m^3)
1st brnch = height to first major branch (m)

G.wt.t = green weight of timber (kg)
G.wt.b = green weight of bark (kg)
D.wt.t = air-dry weight of timber (kg)
D.wt.b = air-dry weight of bark (kg)
G.wt = green weight of tree (kg)
D. wt = air-dry weight of tree (kg)

Vol.t = volume of timber (m^3)
Vol.b = volume of bark (m^3)

gd.t = green density of timber ($g.cm^{-3}$)
gd.b = green density of bark ($g.cm^{-3}$)
dd.t = air-dry density of timber ($g.cm^{-3}$)
dd.b = air-dry density of bark ($g.cm^{-3}$)
gd = green density of tree ($g.cm^{-3}$)
dd = air-dry density of tree ($g.cm^{-3}$)

Appendix XIV. Tree mensuration data for dead *E. laevopinea* and *E. melliodora* (13 trees).

Spp.	~ Age *	HT	DBH(ub)	Dwt.t	MC	Vol.t	DD.t
SB	30	13	31.5	441	16.6	0.559	0.789
SB	30	16.5	47.0	1125	20.1	1.369	0.822
SB	30	14	25.5	257	16.6	0.316	0.813
SB	30	15.5	34.5	719	-	-	-
SB	30	16	44.5	1070	-	-	-
SB	30	16	48	1610	20.0	2.118	0.760
SB	30	17.5	66	2981	17.4	3.653	0.816
YB	30	7.5	22.5	149	17.1	0.160	0.931
YB	30	14	27	299	14.2	0.323	0.926
YB	30	11.5	21	243	-	-	-
YB	30	10	23.5	175	-	-	-
YB	30	11.5	40	586	15.9	0.652	0.899
YB **	5	12.5	63.5	1770	24.6	1.628	1.026

* estimated age since tree death

** all measurements for the largest yellow box include bark. Assuming a timber : bark volume ratio of about 10:1 and a timber : bark density ratio of about 9:5, timber weight can be recalculated at about 1670 kg with a underbark DBH of about 59 cm.

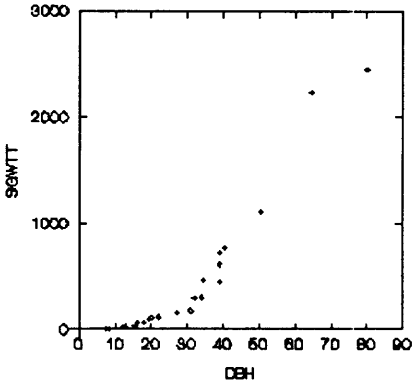
Ht = height (m)
DBH(ub) = underbark diameter at breast height (cm)
Dwt.t = dry weight of timber (kg)
MC = moisture content (%)
Vol.t = volume of timber (m^3)
DD.t = dry density of timber ($g.cm^{-3}$)

Appendix XV. Biomass-DBH plots of harvested trees

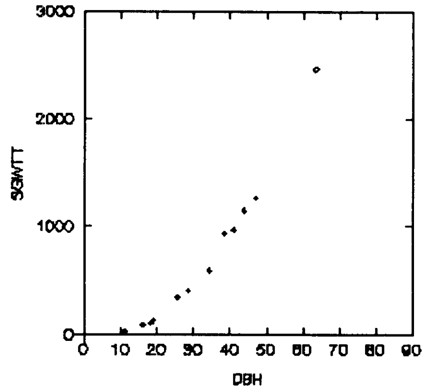
i. Stemwood timber plots

Green weight (kg)

Stringybark

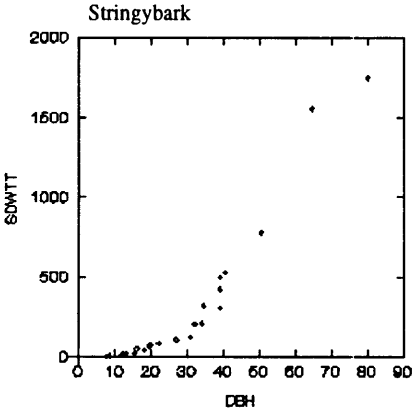


Yellow box

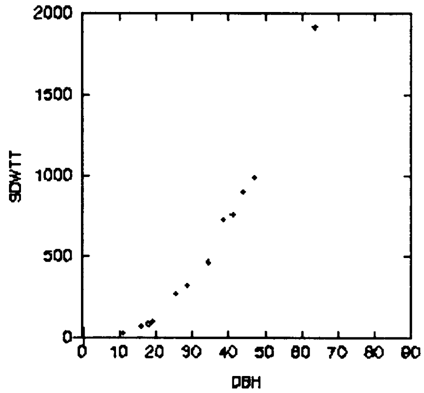


Air-dry weight (kg)

Stringybark

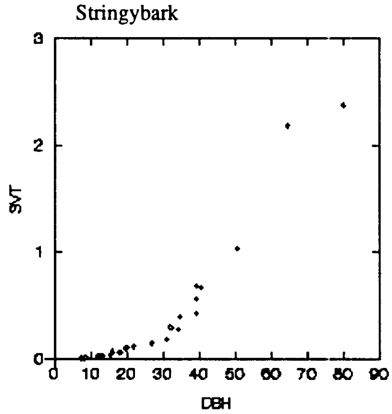


Yellow box

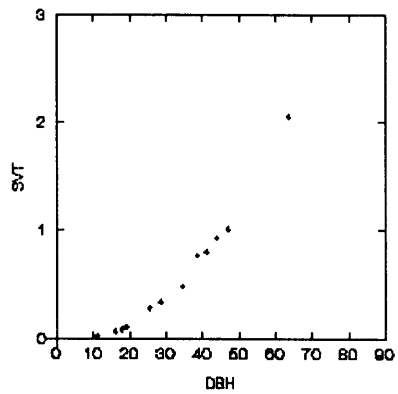


Volume (m^3)

Stringybark



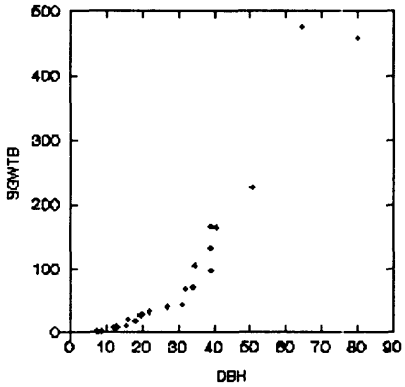
Yellow box



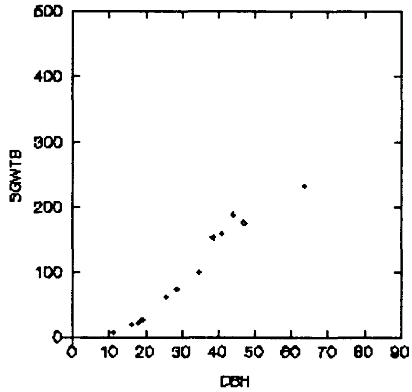
ii. Stemwood bark plots

Green weight (kg)

Stringybark

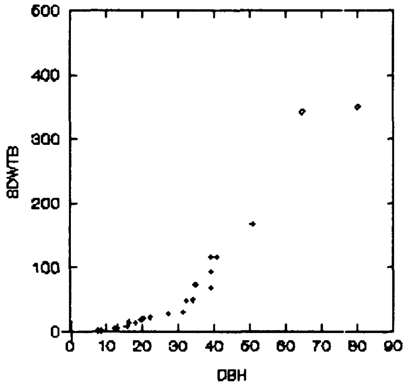


Yellow box

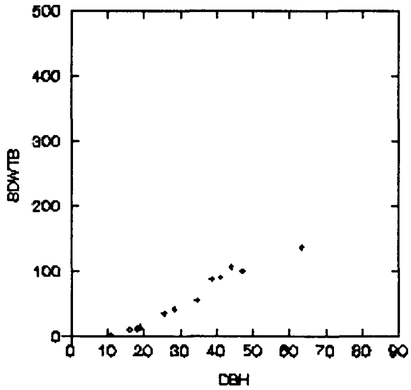


Air-dry weight (kg)

Stringybark

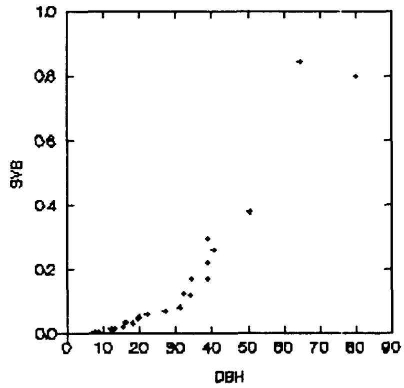


Yellow box

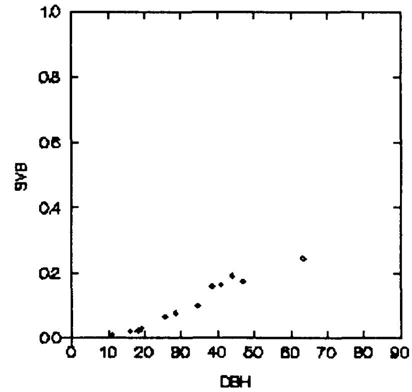


Volume (m^3)

Stringybark



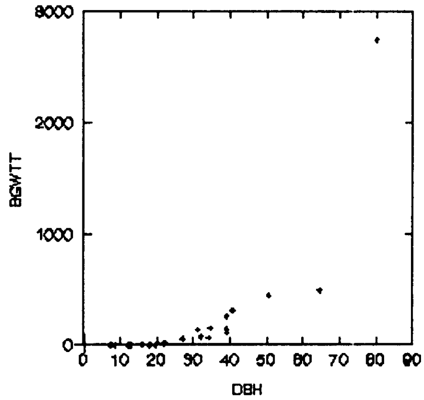
Yellow box



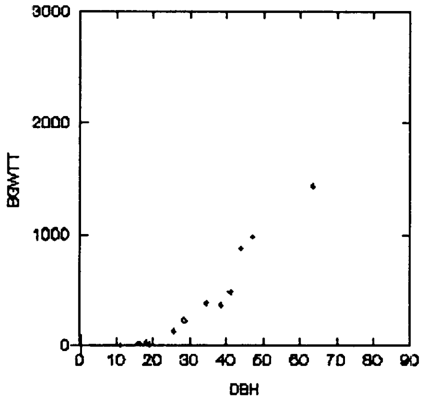
iii. Branchwood timber plots

Green weight (kg)

Stringybark

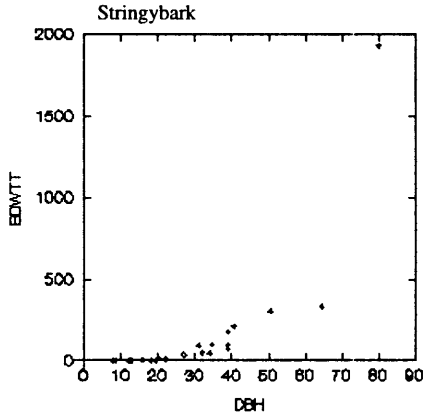


Yellow box

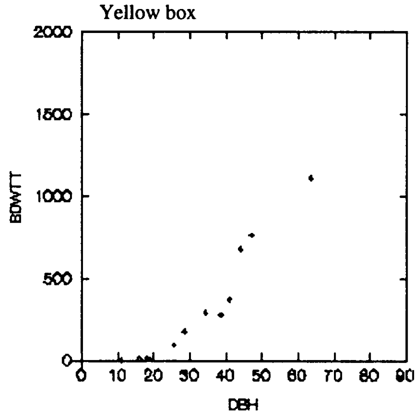


Air-dry weight (kg)

Stringybark

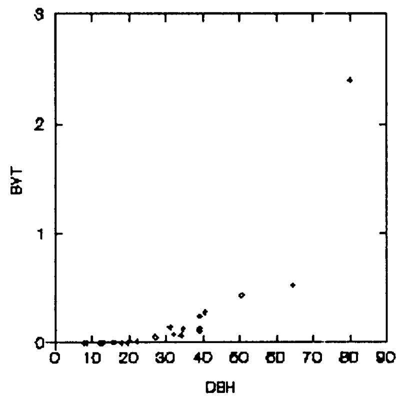


Yellow box

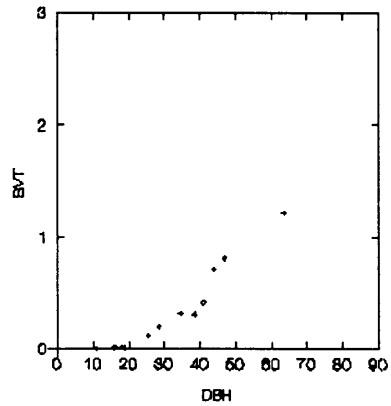


Volume (m^3)

Stringybark



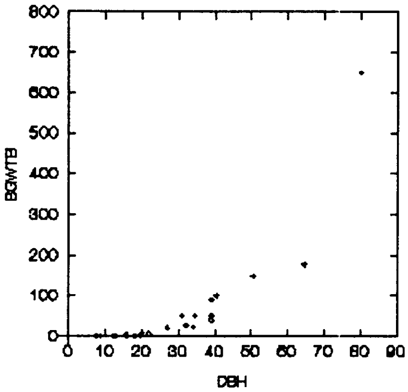
Yellow box



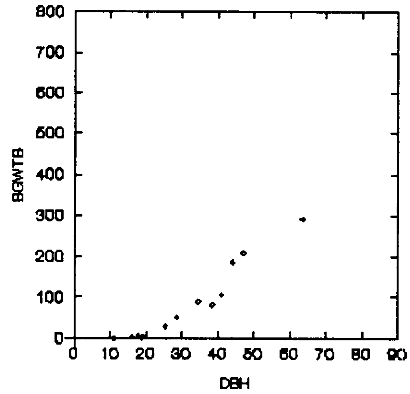
iv. Branchwood bark plots

Green weight (kg)

Stringybark

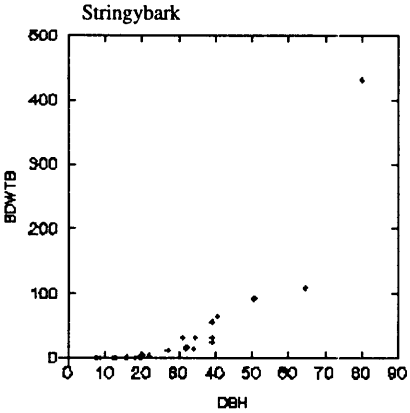


Yellow box

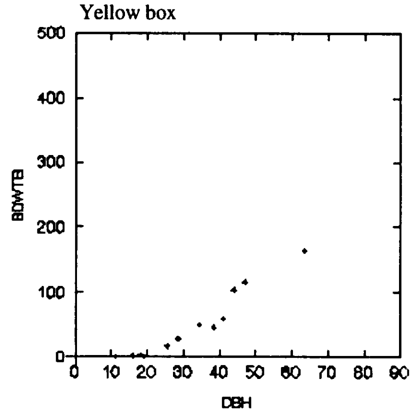


Air-dry weight (kg)

Stringybark

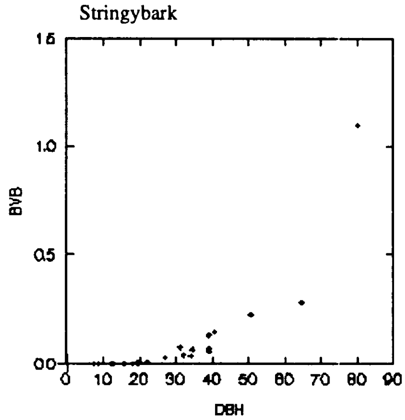


Yellow box

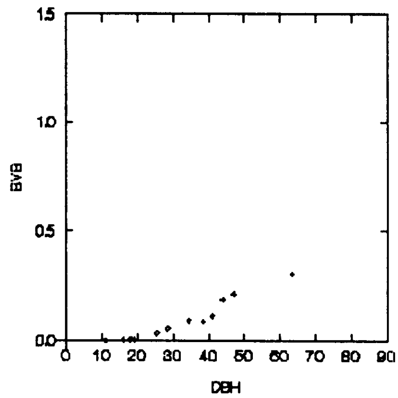


Volume (m^3)

Stringybark

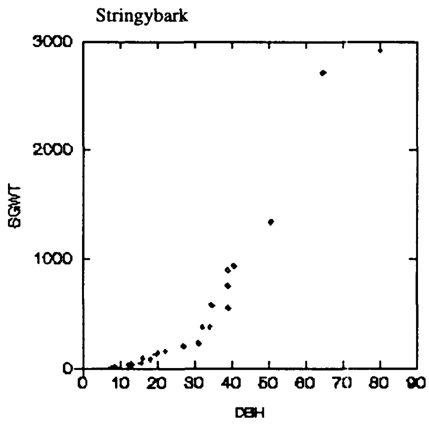


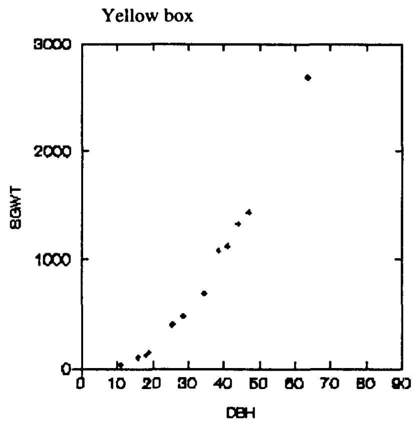
Yellow box



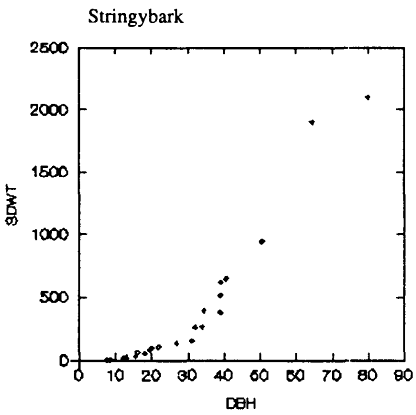
v. Stemwood plots

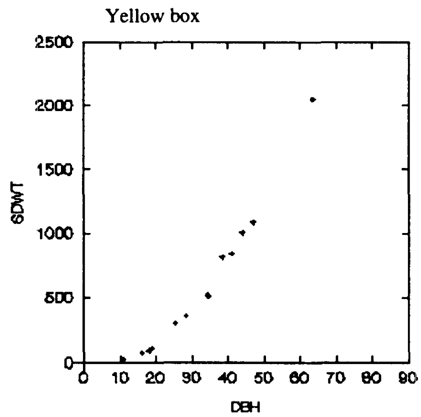
Green weight (kg)



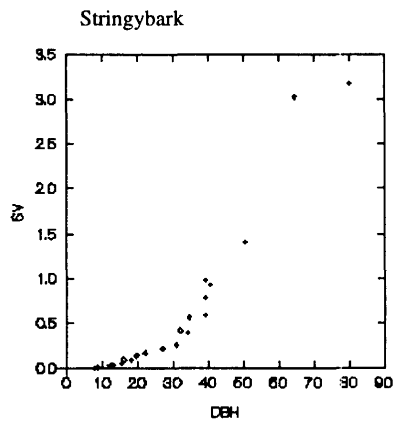


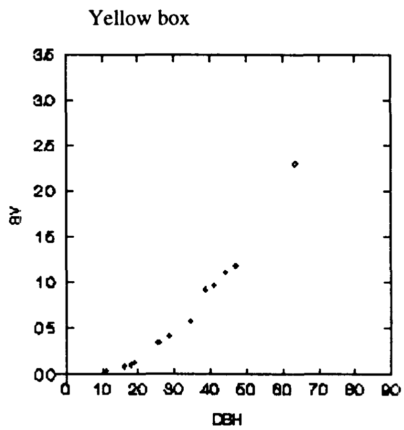
Air-dry weight (kg)





Volume (m^3)

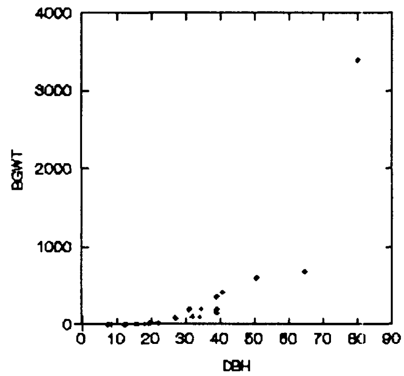




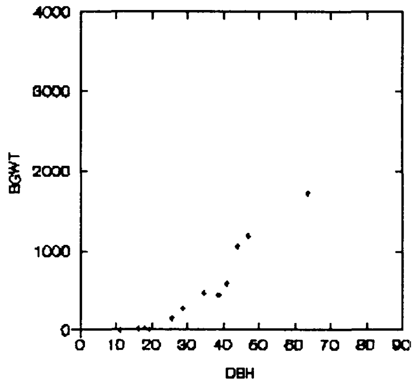
vi. Branchwood plots

Green weight (kg)

Stringybark

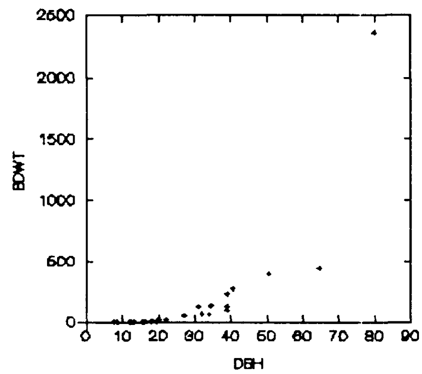


Yellow box

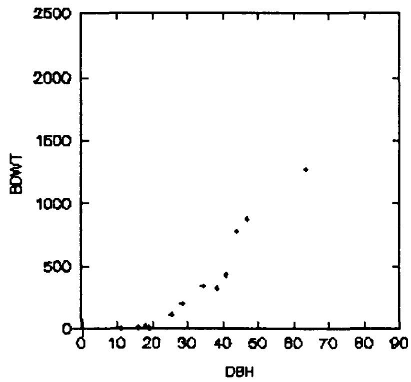


Air-dry weight (kg)

Stringybark

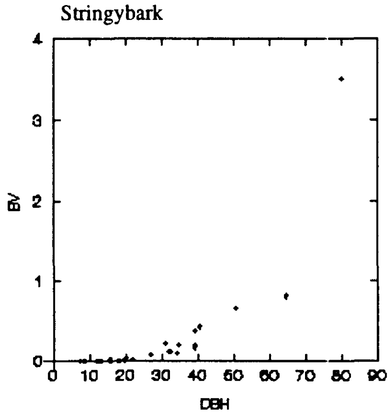


Yellow box

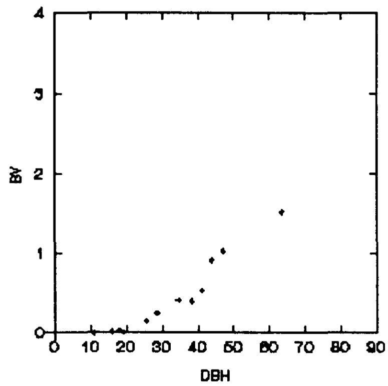


Volume (m^3)

Stringybark



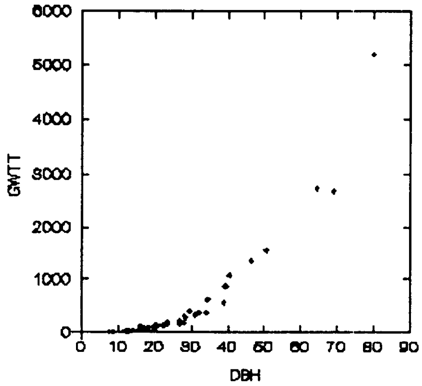
Yellow box



vii. Timber plots

Green weight (kg)

Stringybark



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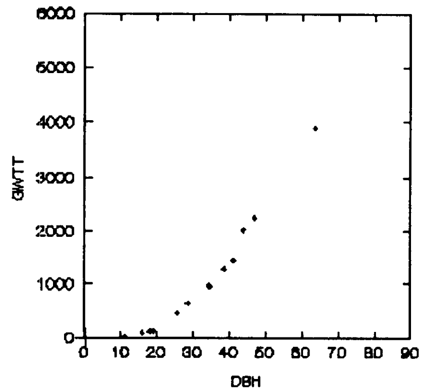
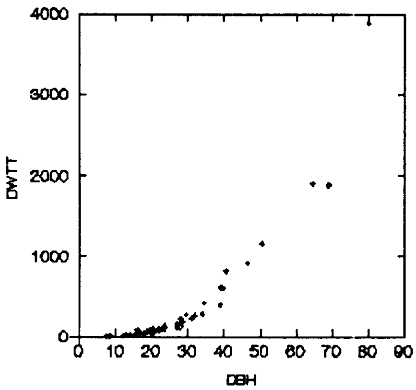
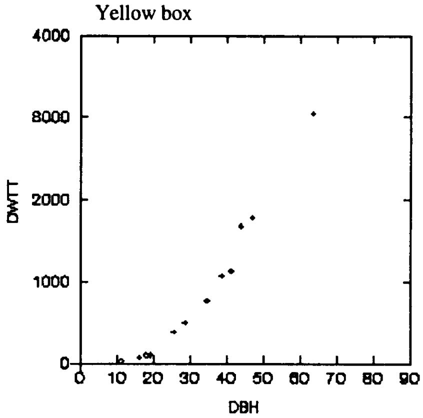


Air-dry weight (kg)

Stringybark

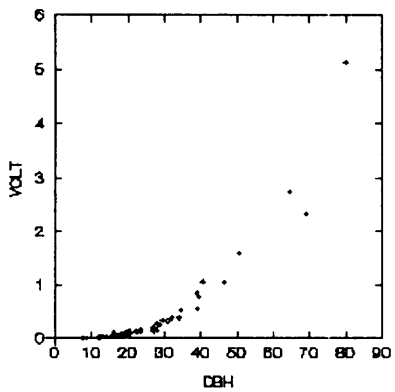


Yellow box



Volume (m^3)

Stringybark



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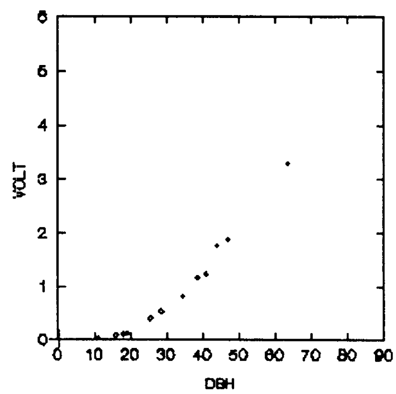
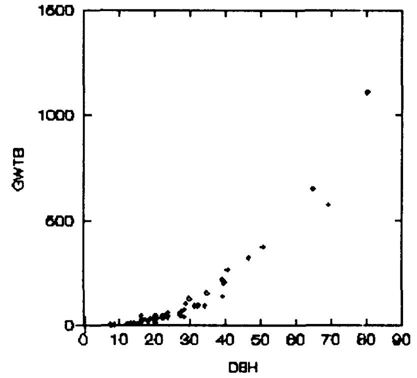


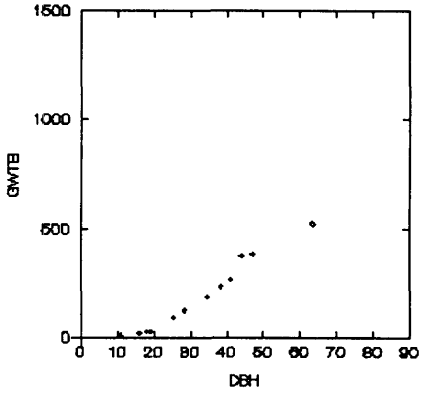
viii. Bark plots

Green weight (kg)

Stringybark

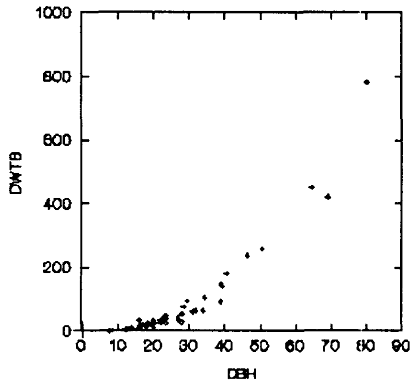


Yellow box

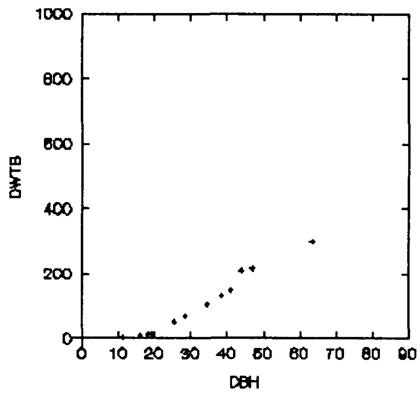


Air-dry weight (kg)

Stringybark

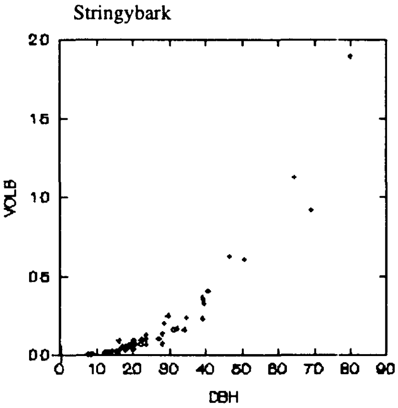


Yellow box

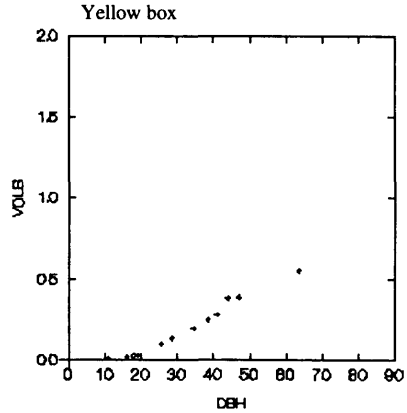


Volume (m^3)

Stringybark



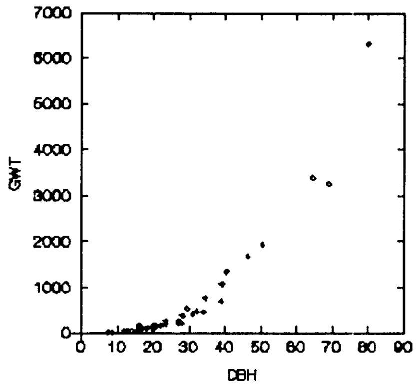
Yellow box



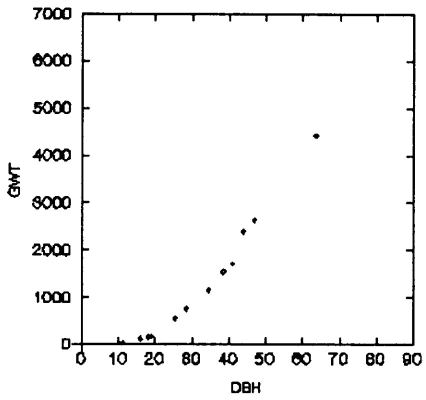
ix. Tree plots

Green weight (kg)

Stringybark

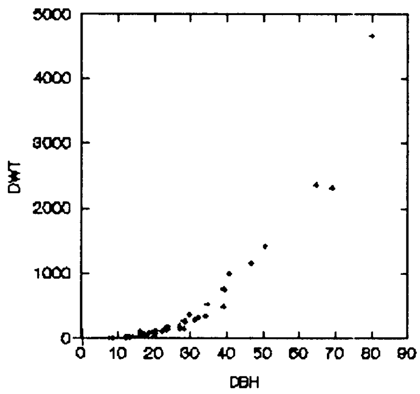


Yellow box

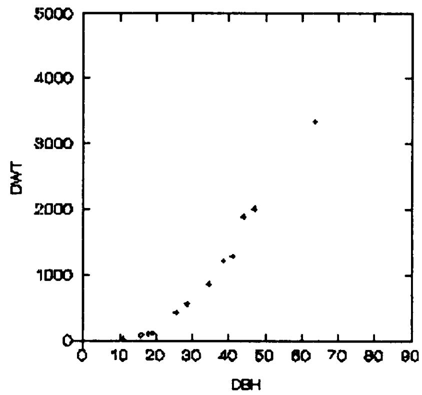


Air-dry weight (kg)

Stringybark

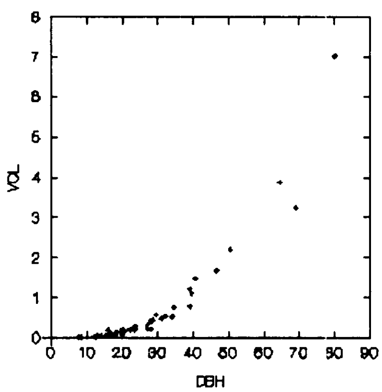


Yellow box

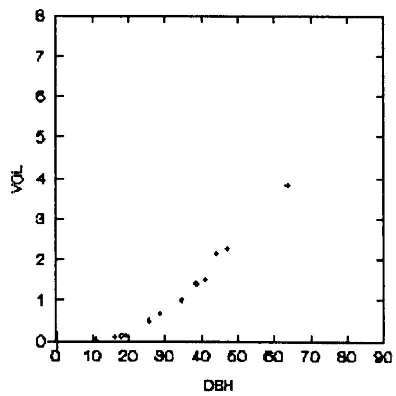


Volume (m^3)

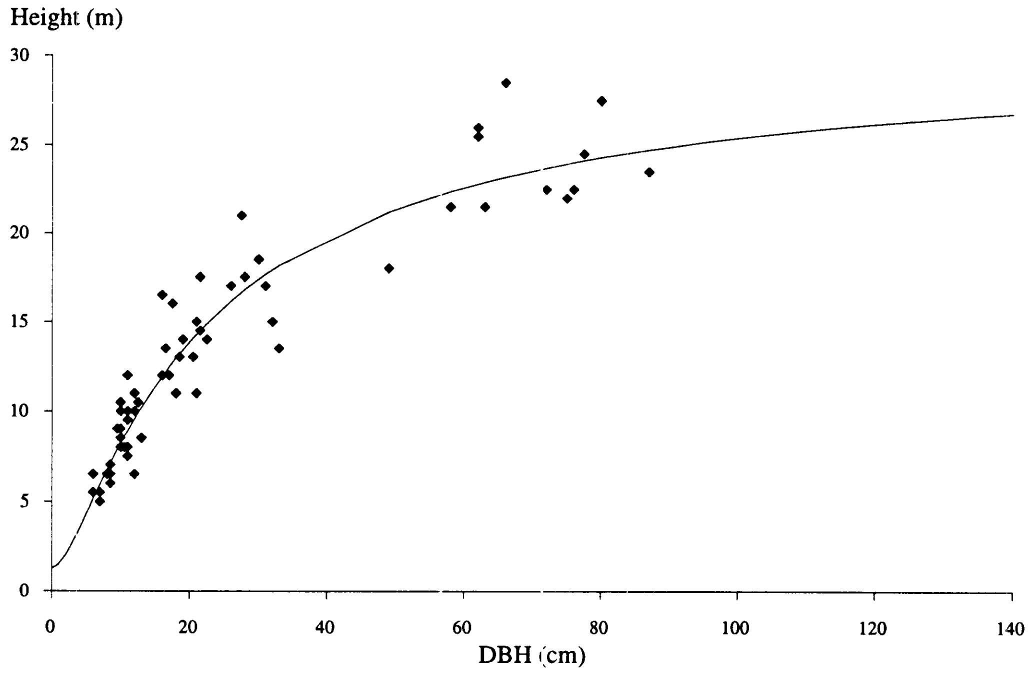
Stringybark



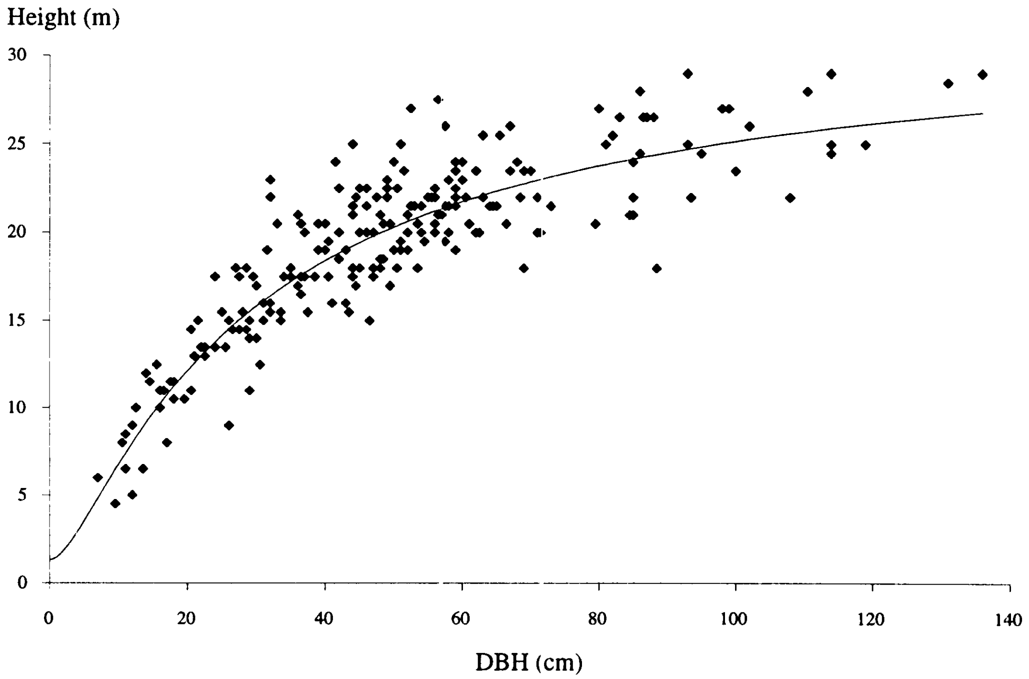
Yellow box



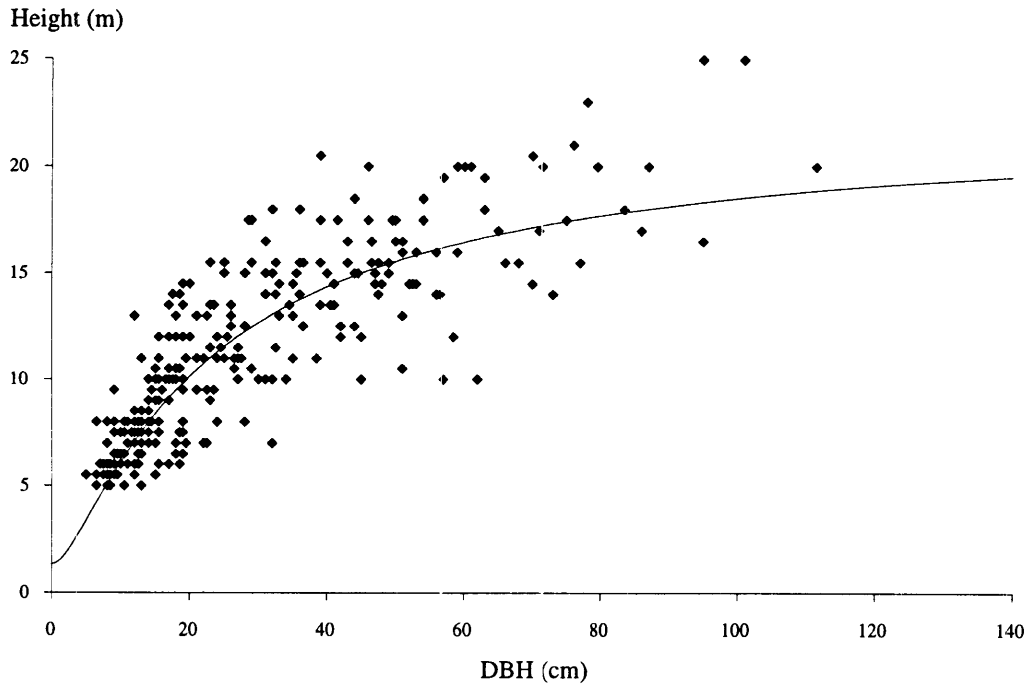
Appendix XVI. Height curves for *Eucalyptus* spp.



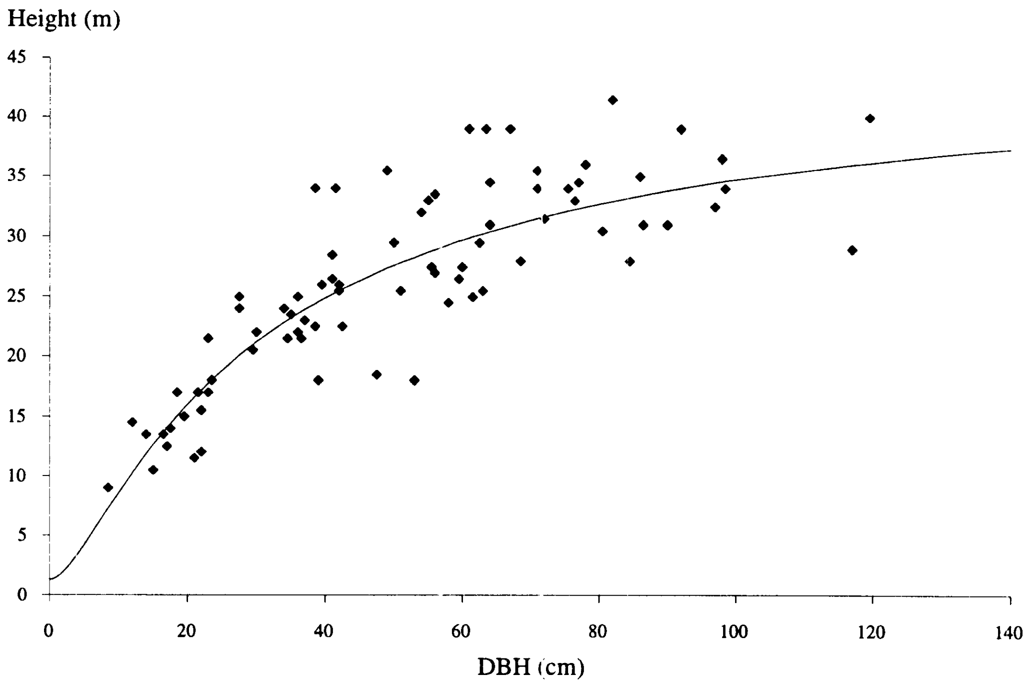
i. Grey Box *E. moluccana* - (SQ7)



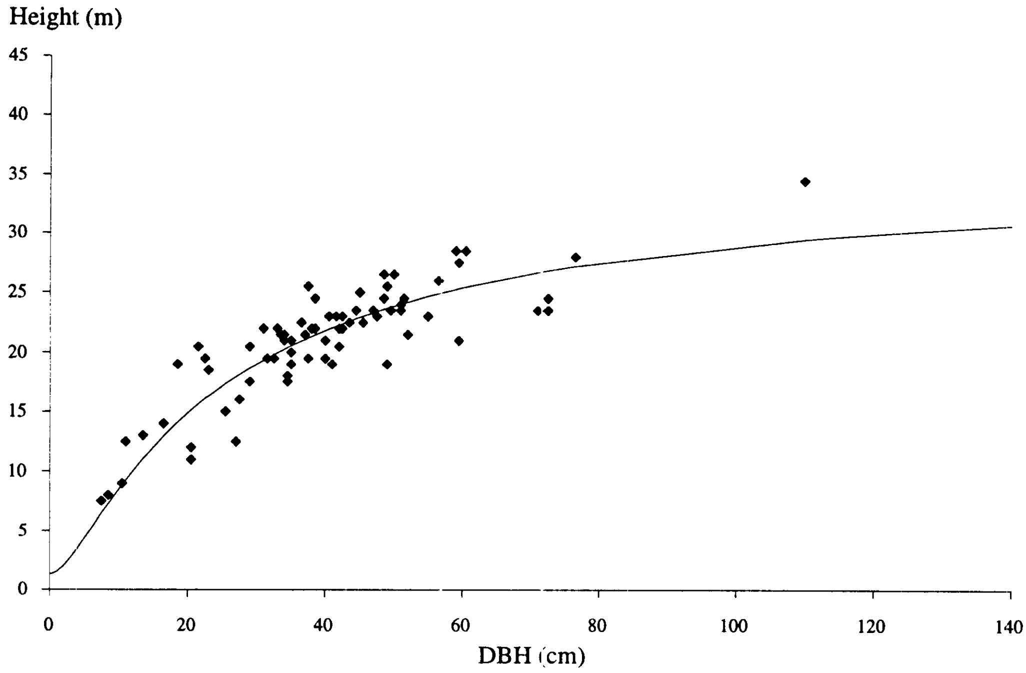
ii. Ironbark *E. sideroxylon* (SQ6-7)



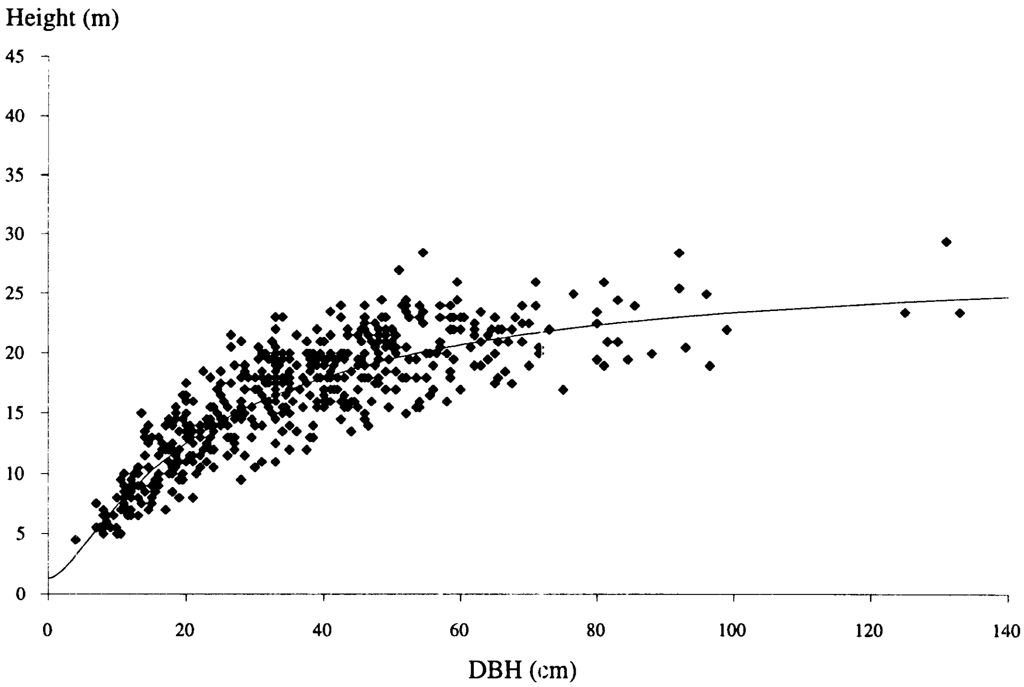
iii. Red gum *E. blakelyi* (SQ6-7)



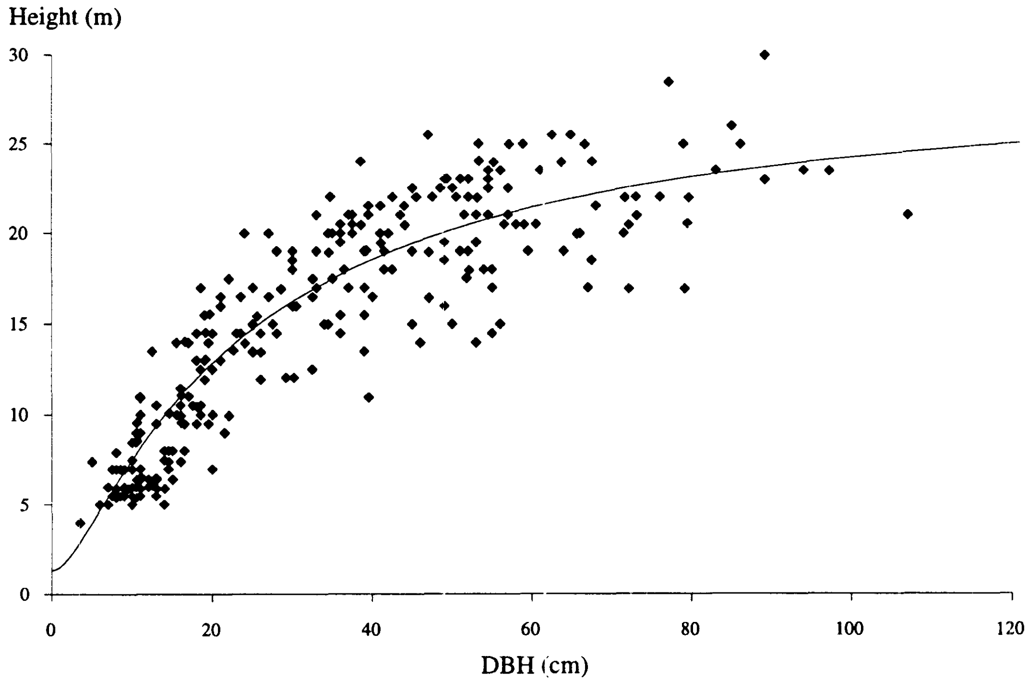
iv. Stringybark *E. caliginosa - E. laevopinea* (SQ1-2-3)



v. Stringybark *E. caliginosa* - *E. laevopinea* (SQ4)

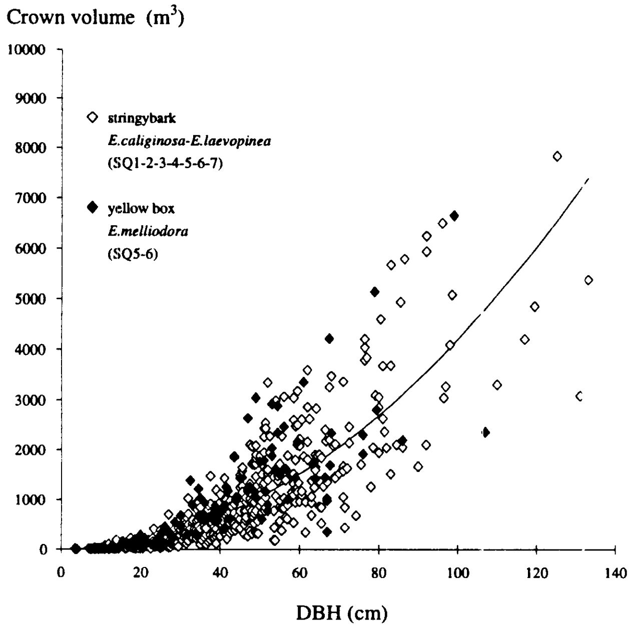


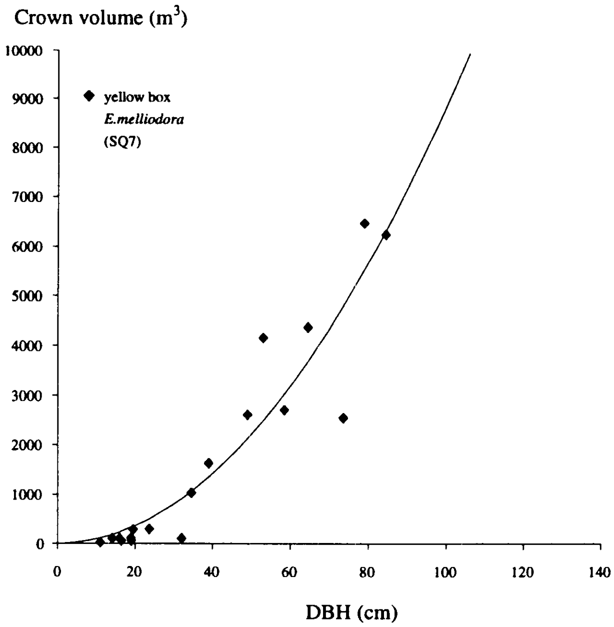
vi. Stringybark *E. caliginosa* - *E. laevopinea* (SQ5-6-7)

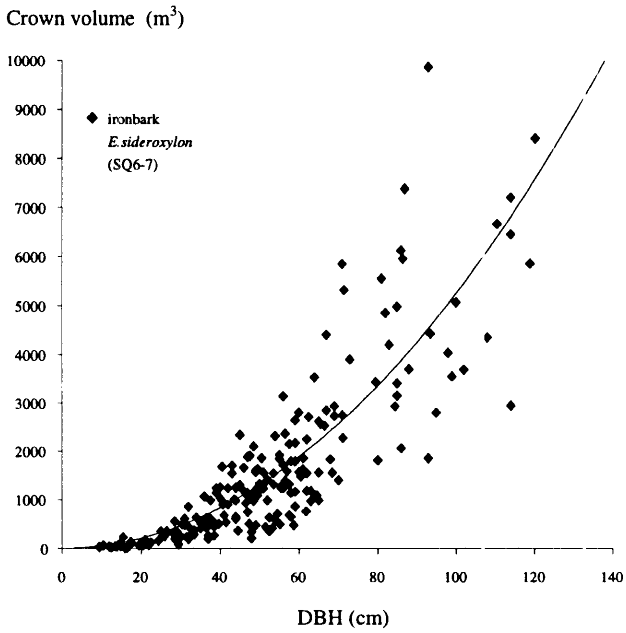


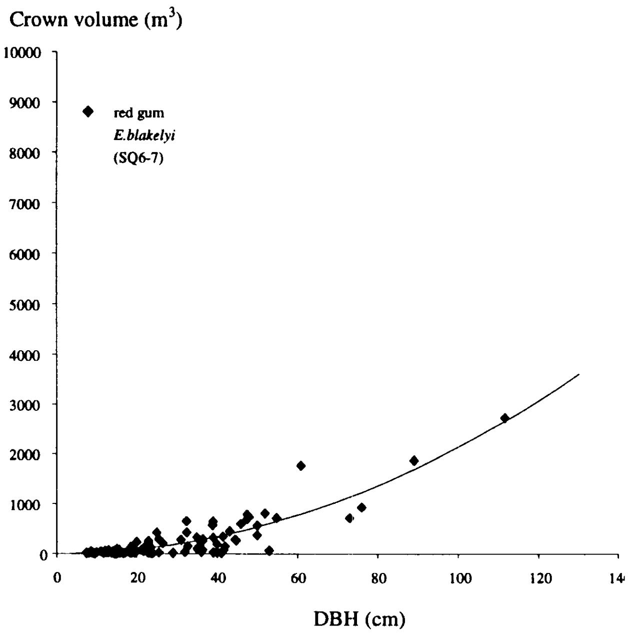
Yellow box *E. melliodora* (SQ5-6-7)

Appendix XVII. Composite crown volume curves for the major fuelwood species sampled









Appendix XVIII. Least square single-variate regression equations for green weight and volume variables of stringybark and yellow box

i. Green weight (kg)

TC*	Tree	SQ	n	Expression	r	Adj.r^2	SE(est)
S-t	SB	1-2-3	75	$= 0.966*(DBH-5)^2$	0.990	0.981	547.7
		4	74	$= 0.807*(DBH-5)^2$	0.987	0.974	288.6
		5	75	$= 0.587*(DBH-5)^2$	0.993	0.987	115.8
		6-7	319	$= 0.644*(DBH-5)^2$	0.989	0.978	264.9
	YB	5-6	246	$= 0.627*(DBH-5)^2$	0.984	0.968	262.8
		7	26	$= 0.692*(DBH-5)^2$	0.988	0.976	255.7
S-b	SB	1-2-3	75	$= 0.204*(DBH-5)^2$	0.989	0.978	124.2
		4	74	$= 0.172*(DBH-5)^2$	0.990	0.980	54.1
		5	75	$= 0.123*(DBH-5)^2$	0.993	0.986	24.6
		6-7	319	$= 0.133*(DBH-5)^2$	0.989	0.978	54.7
	YB	5-6	246	$= 0.056*(DBH-5)^2$	0.923	0.852	54.5
		7	26	$= 0.064*(DBH-5)^2$	0.943	0.888	52.9
B-t	SB	1-2-3-6-7	394	$= 0.040*(DBH-15)^2 + 8.704*(DBH-15)$	0.971	0.942	99.3
		4-5	149	$= 0.054*(DBH-15)^2 + 7.147*(DBH-15)$	0.982	0.963	51.9
	YB	5-6	118	$= 0.346*(DBH-5)^2 + 3.130*(DBH-5)$	0.985	0.969	159.8
		7	18	$= 0.530*(DBH-5)^2$	0.994	0.988	155.4
B-b	SB	1-2-3-6-7	394	$= 0.015*(DBH-15)^2 + 2.955*(DBH-15)$	0.967	0.935	36.7
		4-5	149	$= 0.020*(DBH-15)^2 + 2.378*(DBH-15)$	0.979	0.935	19.2
	YB	5-6	118	$= 0.070*(DBH-5)^2 + 0.769*(DBH-5)$	0.983	0.966	35.0
		7	18	$= 0.112*(DBH-5)^2$	0.993	0.987	35.0
S	SB	1-2-3	75	$= 1.170*(DBH-5)^2$	0.990	0.981	669.1
		4	74	$= 0.979*(DBH-5)^2$	0.988	0.975	341.1
		5	75	$= 0.710*(DBH-5)^2$	0.993	0.987	139.5
		6-7	319	$= 0.778*(DBH-5)^2$	0.989	0.978	318.3
	YB	5-6	246	$= 0.678*(DBH-5)^2$	0.981	0.962	313.2
		7	26	$= 0.753*(DBH-5)^2$	0.985	0.970	306.9
B	SB	1-2-3-6-7	394	$= 0.054*(DBH-15)^2 + 11.659*(DBH-15)$	0.970	0.940	136.1
		4-5	149	$= 0.074*(DBH-15)^2 + 9.526*(DBH-15)$	0.981	0.962	71.1
	YB	5-6	118	$= 0.416*(DBH-5)^2 + 3.898*(DBH-5)$	0.984	0.969	194.8
		7	18	$= 0.642*(DBH-5)^2$	0.994	0.988	190.3
t	SB	1-2-3	75	$= 0.992*(DBH-5)^2$	0.988	0.975	644.2
		4-6-7	393	$= 0.840*(DBH-5)^2$	0.973	0.946	530.9
		5	75	$= 0.788*(DBH-5)^2$	0.987	0.975	215.9
	YB	5-6	118	$= 0.870*(DBH-5)^2 + 10.352*(DBH-5)$	0.989	0.977	361.4
		7	18	$= 1.289*(DBH-5)^2$	0.995	0.990	345.6
b	SB	1-2-3	75	$= 0.177*(DBH-5)^2 + 2.845*(DBH-5)$	0.982	0.964	167.7
		4-6-7	393	$= 0.160*(DBH-5)^2 + 1.704*(DBH-5)$	0.962	0.925	139.5
		5	75	$= 0.176*(DBH-5)^2$	0.984	0.969	54.3
	YB	5-6	118	$= 0.052*(DBH-5)^2 + 5.313*(DBH-5)$	0.977	0.954	70.4
		7	18	$= 0.117*(DBH-5)^2 + 4.384*(DBH-5)$	0.989	0.977	76.7
TOT	SB	1-2-3	75	$= 1.202*(DBH-5)^2$	0.987	0.974	805.7
		4-6-7	393	$= 1.027*(DBH-5)^2$	0.971	0.943	670.2
		5	75	$= 0.965*(DBH-5)^2$	0.987	0.973	273.5
	YB	5-6	118	$= 0.992*(DBH-5)^2 + 15.665*(DBH-5)$	0.987	0.975	430.5
		7	18	$= 1.336*(DBH-5)^2 + 9.002*(DBH-5)$	0.995	0.989	425.0

* TC = tree component (S = stem; B = branch; t = timber; b = bark)

ii Volume (m^3)

TC*	Tree	SQ	n	Expression	r	Adj.r^2	SE(est)
S-t	SB	1-2-3	75	$= 0.000932*(DBH-5)^2$	0.991	0.981	0.524
		4	74	$= 0.000773*(DBH-5)^2$	0.982	0.965	0.324
		5	75	$= 0.000572*(DBH-5)^2$	0.993	0.985	0.120
		6-7	319	$= 0.000634*(DBH-5)^2$	0.988	0.976	0.274
	YB	5-6	246	$= 0.000521*(DBH-5)^2$	0.985	0.969	0.214
		7	26	$= 0.000574*(DBH-5)^2$	0.985	0.976	0.208
S-b	SB	1-2-3	75	$= 0.000357*(DBH-5)^2$	0.990	0.980	0.207
		4	74	$= 0.000300*(DBH-5)^2$	0.988	0.977	0.101
		5	75	$= 0.000216*(DBH-5)^2$	0.993	0.987	0.043
		6-7	319	$= 0.000236*(DBH-5)^2$	0.989	0.978	0.096
	YB	5-6	246	$= 0.000060*(DBH-5)^2$	0.929	0.864	0.055
		7	26	$= 0.000067*(DBH-5)^2$	0.947	0.897	0.053
B-t	SB	1-2-3-6-7	394	$= 0.001*(0.048*(DBH-15)^2 + 8.549*(DBH-15))$	0.960	0.922	0.121
		4-5	149	$= 0.001*(0.066*(DBH-15)^2 + 6.653*(DBH-15))$	0.973	0.947	0.063
	YB	5-6	118	$= 0.001*(0.296*(DBH-5)^2 + 2.471*(DBH-5))$	0.985	0.971	0.132
		7	18	$= 0.000445*(DBH-5)^2$	0.994	0.989	0.128
B-b	SB	1-2-3-6-7	394	$= 0.001*(0.026*(DBH-15)^2 + 4.535*(DBH-15))$	0.959	0.919	0.066
		4-5	149	$= 0.001*(0.036*(DBH-15)^2 + 3.499*(DBH-15))$	0.972	0.945	0.034
	YB	5-6	118	$= 0.001*(0.074*(DBH-5)^2 + 0.777*(DBH-5))$	0.983	0.967	0.036
		7	18	$= 0.000117*(DBH-5)^2$	0.994	0.987	0.036
S	SB	1-2-3	75	$= 0.001287*(DBH-5)^2$	0.991	0.981	0.721
		4	74	$= 0.001071*(DBH-5)^2$	0.985	0.970	0.412
		5	75	$= 0.000786*(DBH-5)^2$	0.993	0.986	0.158
		6-7	319	$= 0.000866*(DBH-5)^2$	0.989	0.977	0.363
	YB	5-6	246	$= 0.000575*(DBH-5)^2$	0.981	0.962	0.265
		7	26	$= 0.000638*(DBH-5)^2$	0.985	0.970	0.260
B	SB	1-2-3-6-7	394	$= 0.001*(0.075*(DBH-15)^2 + 13.107*(DBH-15))$	0.959	0.920	0.188
		4-5	149	$= 0.001*(0.102*(DBH-15)^2 + 10.166*(DBH-15))$	0.973	0.946	0.098
	YB	5-6	118	$= 0.001*(0.369*(DBH-5)^2 + 3.245*(DBH-5))$	0.985	0.970	0.169
		7	18	$= 0.000562*(DBH-5)^2$	0.994	0.989	0.163
t	SB	1-2-3	75	$= 0.000874*(DBH-5)^2$	0.978	0.957	0.754
		4-6-7	393	$= 0.001*(0.752*(DBH-5)^2 + 3.298*(DBH-5))$	0.956	0.913	0.651
		5	75	$= 0.000767*(DBH-5)^2$	0.979	0.959	0.271
	YB	5-6	118	$= 0.001*(0.730*(DBH-5)^2 + 8.318*(DBH-5))$	0.989	0.978	0.294
		7	18	$= 0.001061*(DBH-5)^2$	0.995	0.990	0.283
b	SB	1-2-3	75	$= 0.001*(0.264*(DBH-5)^2 + 6.272*(DBH-5))$	0.976	0.952	0.316
		4-6-7	393	$= 0.001*(0.252*(DBH-5)^2 + 3.986*(DBH-5))$	0.950	0.903	0.108
		5	75	$= 0.000301*(DBH-5)^2$	0.979	0.958	0.108
	YB	5-6	118	$= 0.001*(0.057*(DBH-5)^2 + 5.441*(DBH-5))$	0.978	0.956	0.072
		7	18	$= 0.001*(0.121*(DBH-5)^2 + 4.549*(DBH-5))$	0.990	0.978	0.078
TOT	SB	1-2-3	75	$= 0.001210*(DBH-5)^2$	0.977	0.955	1.068
		4-6-7	393	$= 0.001*(1.042*(DBH-5)^2 + 4.993*(DBH-5))$	0.954	0.911	0.924
		5	75	$= 0.001070*(DBH-5)^2$	0.978	0.957	0.385
	YB	5-6	118	$= 0.001*(0.760*(DBH-5)^2 + 15.875*(DBH-5))$	0.987	0.974	0.377
		7	18	$= 0.001*(1.105*(DBH-5)^2 + 10.458*(DBH-5))$	0.994	0.988	0.377

* TC = tree component (S = stem; B = branch; t = timber; b = bark)

Appendix XIX. Derivation of volume functions for grey box (*E. moluccana*) and red gum (*E. blakelyi*)

i. Grey box (*E. moluccana*)

(Also applies to white box (*E. albens*) which co-exists with *E. moluccana*)

The height-DBH relationship for grey box SQ6-7 is similar to that of yellow box SQ3-5-6-7 (Table 3.16; Figure 3.14) and the CNVOL-DBH relationship for grey box SQ6-7 is similar to that of stringybark SQ6-7 (J. Wall 1995, unpubl. data). Assuming that the height-DBH relationship contributes to total stemwood volume and CNVOL-DBH contributes to total branchwood volume, then from the respective functions of stem and branch volume:

$V_{stem} = 0.000575*(DBH-5)^2$ (Appendix XVIII)
$V_{brnch} = 0.001*(0.075*(DBH-15)^2 + 13.107*(DBH-15))$ (Appendix XVIII)

a composite tree volume function is simply calculated as the sum Vstem and Vbrnch.

$V_{tree} = 0.001*(0.575*(DBH-5)^2 + 0.075*(DBH-15)^2 + 13.107*(DBH-15))$

Like stringybark, this equation assumes that fuelwood sized branchwood does not form until DBH exceeds 15 cm. Caution must therefore be taken to eliminate negative partial values in the equation when inserting DBH values less than 15 cm.

ii. Red gum (*E. blakelyi*)

Height and crown relationships in red gum were found to differ significantly from any of the pooled stringybark and yellow box classes (Tables 3.16 and 3.19, respectively). In order to construct a volume function for red gum, it was therefore necessary to investigate the HT-DBH and CNVOL-DBH functions of red gum as compared to those of some other species-site quality group. It is evident from Figures 3.14 and 3.15 that stringybark SQ5-6-7 best resembles red gum in terms of height and crown volume. The functions to be compared are:

	RED GUM SQ5-6-7	STRINGYBARK SQ5-6-7
HT =	$(DBH)^2 / (2.389+0.217*(DBH))^2 + 1.3$	$(DBH)^2 / (2.153+0.191*(DBH))^2 + 1.3$
CNVOL =	$0.214*(DBH)^2$	$0.419*(DBH)^2$

(from Tables 3.15 and 3.20)

The height ratio of red gum to stringybark averages about 0.80 whereas the CNVOL ratio is about 0.50. Assuming the HT-DBH relationship contributes to total stemwood volume and CNVOL-DBH contributes to total branchwood volume, then the individual stem and branch volume functions for stringybark SQ5 given as:

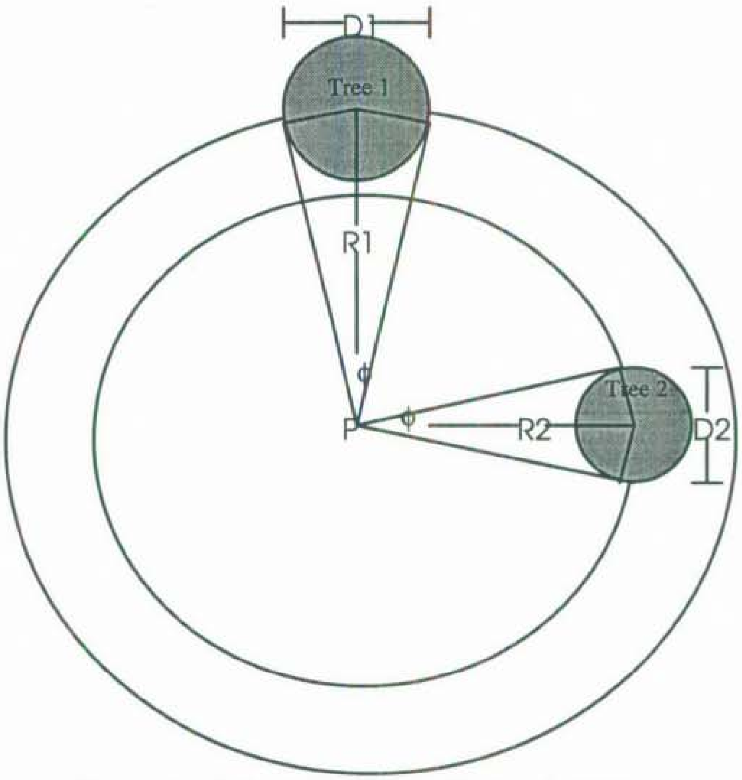
$V_{stem} = 0.000786*(DBH-5)^2$ (Appendix XVIII)
$V_{brnch} = 0.001*(0.102*(DBH-5)^2 + 10.166*(DBH-15))$ (Appendix XVIII)

can be modified according to the ratios then combined to give a tree volume relationship for red gum:

$V_{tree} = 0.000634*(DBH-5)^2 + 0.005083*(DBH-15)$.

Appendix XX. Theory of Bitterlich sampling

From a sampling point P, the overbark DBH of 2 trees (denoted D1 and D2) subtend a common angle ϕ at distances R1 and R2 respectively.



Geometric relationship between critical angle (ϕ), tree DBH (D), and distance from sampling point to stem (R) (adapted from Husch *et al.* 1972).

From the above figure it can be shown that:

$$\sin\left(\frac{\phi}{2}\right) = \frac{D_1}{2 \cdot R_1} = \frac{D_2}{2 \cdot R_2}$$

$$\therefore \phi = 2 \cdot \sin^{-1}\left(\frac{D_i}{2 \cdot R_i}\right)$$

where D_i and R_i are the respective DBH (m) and distance (m) to any tree i. It can also be shown that:

$$a_i = \pi \cdot \left(\frac{D_i}{4}\right)^2$$

$$A_i = \pi \cdot (R_i)^2$$

where a_i is the cross-sectional area of tree i at DBH height and A_i is the area of the circle about P (whose circumference passes through tree i and whose radius is R_i) .

Using BAF1, it follows that the ratio of a_i:A_i = 1:10000.

$\therefore A_i = 10000.a_i$.

$\therefore \pi.(R_i)^2 = 10000.\pi.(^{D_i}/_2)^2$

$\therefore R_i = 50.D_i$.

Using BAF2, it follows that the ratio of a_i:A_i = 1:5000.

$\therefore A_i = 5000.a_i$.

$\therefore \pi.(R_i)^2 = 5000.\pi.(^{D_i}/_2)^2$

$\therefore R_i = 35.36.(D_i)$.

Application of the above expressions reveal that trees located no farther than 50 times their DBH from the sampling point are tallied using BAF1 and trees located within 35.36 times their DBH from P are tallied using BAF2. Thus, a tree with DBH of 50 cm must be within 25 m of P to be tallied using BAF1, and a tree of 22 cm DBH must be within 7.78 m to be tallied using BAF 2.

Appendix XXI. Stand parameters for sites assessed using point-centred quarter and horizontal (Bitterlich) sampling.

Site	S.T.[1]	Cover [2]	Veg [3]	SQ [4]	LT [5]	$trees.ha^{-1}$	BA ($m^2.ha^{-1}$)	AvDBH (cm)
1	1	3	3	6	3	50	5.7	38.1
2	1	1	2	6	3	203	12.2	27.7
3	2	2	2	6	3	291	15.9	26.4
4	1	3	3	6	3	107	2.2	16.2
5	2	2	2	6	1	334	18.5	26.6
6	1	2	3	6	3	66	7.2	37.3
7	1	2	3	7	3	363	11.3	19.9
8	2	2	2	6	1	462	12.7	18.7
9	2	2	2	6	3	192	12.0	28.2
10	2	2	2	6	1	244	10.3	23.2
11	2	2	2	6	1	121	12.8	36.7
12	1	2	3	7	3	260	14.4	26.6
13	2	2	2	7	3	181	14.8	32.3
14	1	3	2	6	3	128	7.0	26.4
15	1	2	3	6	3	58	9.0	44.4
16	2	2	2	7	1	223	18.9	32.8
17	2	1	2	7	3	452	23.3	25.6
18	2	1	2	7	1	363	16.9	24.3
19	2	2	2	7	1	207	16.0	31.4
20	2	2	2	7	3	427	15.4	21.4
21	1	2	3	7	3	207	13.9	29.2
22	1	3	3	7	3	19	1.7	33.8
23	1	3	3	7	3	32	3.1	35.1
24	1	4	3	7	3	4	0.4	35.7
25	1	3	3	7	3	96	8.7	34.0
26	2	2	3	6	3	336	17.5	25.8
27	2	2	3	7	3	407	17.9	23.7
28	1	2	1	6	3	82	11.7	42.6
29	2	1	1	5	1	710	33.1	24.4
30	2	1	1	5	1	704	29.0	22.9
31	1	2	3	6	3	154	10.8	29.9
32	1	3	3	6	3	57	6.1	36.9
33	1	2	1	6	3	171	18.3	36.9
34	1	2	3	6	3	138	4.1	19.4
35	1	2	1	6	3	99	6.2	28.2
36	1	3	4	6	3	85	4.9	27.1
37	1	4	4	6	3	37	6.4	46.9
38	1	3	3	6	3	33	2.9	33.5
39	1	3	3	5	3	30	5.7	49.2
40	1	3	3	5	3	43	10.8	56.6
41	2	2	1	6	1	1143	24.7	16.6
42	2	1	1	5	1	329	29.7	33.9
43	2	1	1	5	1	342	30.4	33.6
44	2	1	3	6	1	471	19.4	22.9
45	2	2	1	6	1	74	15.8	52.1
46	1	4	4	6	3	4	0.5	39.9
47	1	4	3	6	3	3	0.8	58.3
48	1	4	3	6	3	4	0.8	50.5
49	1	4	4	6	3	3	0.4	41.2
50	1	5	4	6	3	1	0.5	79.8

Site	S.T.[1]	Cover [2]	Veg [3]	SQ [4]	LT [5]	trees.ha^{-1}	BA ($m^2 ha^{-1}$)	AvDBH (cm)
51	1	3	3	7	3	50	9.2	48.4
52	1	2	4	6	3	51	9.6	49.0
53	1	3	4	6	3	64	7.8	39.4
54	1	4	4	7	3	2	0.5	56.4
55	1	4	3	7	3	65	2.9	23.8
56	1	3	4	4	3	31	2.5	32.0
57	1	3	4	4	3	36	2.5	29.7
58	1	3	4	3	3	66	9.2	42.1
59	1	3	4	5	3	91	3.8	23.1
60	2	1	1	4	2	637	32.3	25.4
61	2	1	1	4	2	653	40.2	28.0
62	1	4	4	4	3	27	6.0	53.2
63	1	2	1	5	3	89	5.0	26.7
64	2	1	1	3	1	417	26.2	28.3
65	2	2	1	5	1	400	20.0	25.2
66	1	2	1	6	3	256	15.9	28.1
67	1	2	1	6	3	421	19.6	24.3
68	1	3	3	6	3	60	11.8	50.0
69	1	3	1	6	3	72	6.7	34.4
70	1	4	4	6	3	19	2.8	43.3
71	1	4	4	6	3	60	2.8	24.4
72	1	4	4	6	3	7	1.0	42.6
73	1	4	4	6	3	21	2.3	37.3
74	2	2	1	6	1	597	14.6	17.6
75	2	2	1	6	1	526	16.3	19.9
76	1	1	1	6	2	200	11.3	26.8
77	1	2	1	6	2	102	11.2	37.4
78	1	2	1	6	2	150	13.2	33.5
79	2	1	1	6	2	280	18.3	28.8
80	2	2	1	6	1	369	14.4	22.3
81	1	4	4	6	3	7	2.8	71.4
82	1	3	3	6	3	25	1.0	22.6
83	1	1	1	6	2	421	26.5	28.3
84	1	1	1	6	2	189	14.6	31.4
85	2	1	1	6	2	517	22.3	23.4
86	1	5	4	6	3	1	0.1	35.7
87	1	3	1	6	3	13	1.2	34.3
88	1	4	3	6	3	5	0.6	39.1
89	1	5	4	7	3	3	0.5	46.1
90	2	2	4	7	1	503	22.8	24.0
91	2	1	1	6	1	644	22.6	21.1
92	2	2	4	6	1	388	22.5	27.2
93	1	4	4	6	3	6	1.6	58.3
94	2	2	1	6	1	626	23.3	21.8
95	1	1	4	5	3	240	11.6	24.8
96	1	3	4	4	3	44	4.5	36.1
97	1	3	4	5	3	103	1.0	11.1
98	2	2	1	6	1	366	11.9	20.3
99	2	1	1	5	2	697	32.5	24.4
100	2	1	1	7	1	320	18.3	27.0

Site	S.T.[1]	Cover [2]	Veg [3]	SQ [4]	LT [5]	trees.ha^{-1}	BA (m^2.ha^{-1})	AvDBH (cm)
101	1	2	1	7	3	166	12.3	30.7
102	2	2	1	7	1	737	18.4	17.8
103	1	1	1	7	3	319	21.3	29.2
104	2	2	1	7	1	316	19.4	28.0
105	1	3	1	6	3	106	14.0	41.0
106	1	3	1	6	3	41	4.1	35.7
107	1	3	3	6	3	172	4.4	18.0
108	1	2	1	6	3	235	17.2	30.5
109	1	3	1	3	3	88	8.7	35.5
110	1	2	4	2	3	149	4.0	18.5
111	2	1	1	4	1	1459	24.3	14.6
112	2	1	1	4	1	797	23.2	19.3
113	2	1	1	3	1	610	32.5	26.0
114	2	1	1	3	1	831	25.3	19.7
115	2	1	1	1	2	865	40.5	24.4
116	2	2	1	1	2	461	26.3	27.0
117	2	2	1	1	2	369	24.4	29.0
118	2	1	1	4	2	623	27.1	23.5
119	2	1	1	4	2	929	34.3	21.7
120	2	1	1	4	2	2164	45.3	16.3
121	2	1	1	3	2	538	33.1	28.0
122	2	1	1	2	2	331	34.8	36.6
123	1	3	3	6	3	35	3.5	35.7

1. S.T. = sampling technique (1 = point-centred quarter method; 2 = Bitterlich method)
2. Cover = cover class (1 = closed forest; 2 = open forest; 3 = woodland; 4 = scattered trees; 5 = isolated trees)
3. Veg. = vegetation type (1 = stringybark; 2 = ironbark; 3 = box/gum; 4 = light)
4. SQ = site quality (1 > 1000 mm.yr^{-1}; 2 = 950-1000 mm.yr^{-1}; 3 = 900-950 mm.yr^{-1}; 4 = 850-900 mm.yr^{-1}; 5 = 800-850 mm.yr^{-1}; 6 = 750-800 mm.yr^{-1}; 7 < 750 mm.yr^{-1})
5. LT = land tenure (1 = freehold; 2 = state forest; 3 = travelling stock reserve)

Appendix XXII. Species composition and biomass apportionment in 21 eucalypt stand classes in the study area.

Notation

BA = basal area ($m^2.ha^{-1}$)
Dens. = tree density ($stems.ha^{-1}$)
DWt = air-dry weight ($t.ha^{-1}$) of useful fuelwood timber

(Useful fuelwood timber includes all dead trees ≤ 55 cm DBHub, all live trees with DBHob 15-55 cm, and all branches of live trees >55 cm DBHob. It does not include the timber in 'light' species, acacia or casuarina)

DSB	dead stringybark (includes dead blackbutt)
SB	stringybark (includes blackbutt)
DYB	dead yellow box
YB	yellow box
DRG	dead red gum
RG	red gum
DIB	dead ironbark
IB	ironbark
DGB	dead grey box (includes dead white box)
GB	grey box (includes white box)
D light	dead 'light' species (includes various gums and peppermints, apple box, sallee and angophora)
light	light species
D/L Ac	Acacia (dead or alive)
D/L Cas	Casuarina (dead or alive)
t	timber
b	bark

Number : 1
Site(s) : 115
Description : Styx River State Forest (plateau) - stringybark/blackbutt closed forest (SQ1)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.1	0.6	0.3	0.4	0.6	1.0	1.3	0.8	5.1
	SB	1.9	3.3	3.8	3.8	3.2	5.9	2.9	0.9	25.7
	DYB									
	YB									
	DRG									
	RG									
	DIB									
	IB									
	DGB									
	GB									
	D light	0.1	0.2		0.1	0.3	0.4	0.2	0.3	1.6
	Light	0.3	0.7	0.7	1.0	0.5	1.6	1.6	0.4	6.8
	D/L Ac	0.9	0.1							1.0
	D/L Cas	0.1	0.2							0.3
	ALL	3.4	5.1	4.8	5.3	4.6	8.9	6.0	2.4	40.5

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB	17.6	18.2	4.6	3.0	3.0	3.1	2.3	0.7	52.5
	SB	204.2	120.3	55.2	32.9	16.3	18.3	4.9	0.8	452.9
	DYB									
	YB									
	DRG									
	RG									
	DIB									
	IB									
	DGB									
	GB									
	D light	26.0	8.1		0.9	1.4	1.1	0.3	0.3	38.1
	Light	31.3	25.5	10.2	7.8	2.5	5.1	2.7	0.4	85.5
	D/L Ac	217.4	5.3							222.7
	D/L Cas	7.5	5.8							13.3
	ALL	504.3	183.2	70.0	44.6	23.2	27.6	10.2	2.2	865.3

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB	0.15	2.97	1.76	2.65	4.17				11.70
	SB (t)		16.09	23.65	25.86	23.30	37.29	11.05	1.93	139.17
	SB (b)		5.64	6.67	6.69	5.63	8.80	2.70	0.50	36.63
	DYB									
	YB (t)									
	YB (b)									
	DRG									
	RG (t)									
	RG (b)									
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	0.15	24.70	32.08	35.20	33.10	46.09	13.75	2.43	187.50

Number : 2
Site(s) : 119,120,121,122
Description : Winterbourne State Forest - stringybark/blackbutt closed forest (SQ2-3-4)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.20	0.20	0.20	0.35	0.15	0.25	0.20	0.08	1.6
	SB	2.22	2.26	3.45	4.52	4.53	5.95	3.16	0.83	26.9
	DYB									
	YB									
	DRG									
	RG									
	DIB									
	IB									
	DGB									
	GB									
	D light	0.08	0.05	0.03	0.03		0.05	0.02	0.03	0.3
	Light	0.52	0.85	0.53	0.68	0.83	1.35	0.92	0.20	6.2
	D/L Ac	0.12	0.02							0.1
	D/L Cas	1.15	0.66	0.08	0.03	0.03				2.0
	ALL	4.3	4.1	4.3	5.7	5.6	7.6	4.3	1.2	37.1

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB	25.07	6.28	3.32	3.00	0.77	0.85	0.32	0.08	39.7
	SB	377.38	78.60	50.19	36.82	23.77	19.00	5.64	0.70	592.1
	DYB									
	YB									
	DRG									
	RG									
	DIB									
	IB									
	DGB									
	GB									
	D light	9.59	1.96	0.58	0.31		0.18	0.03	0.03	12.7
	Light	81.15	29.98	8.14	5.74	4.27	4.29	1.60	0.19	135.7
	D/L Ac	21.78	0.78							22.6
	D/L Cas	160.07	26.03	1.34	0.25	0.19				187.9
	ALL	675.1	143.7	63.7	46.2	29.0	24.4	7.6	1.0	990.7

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB	0.44	0.89	1.06	2.08	0.96				5.43
	SB (t)		10.45	19.97	28.87	30.62	35.56	11.63	1.76	138.86
	SB (b)		3.34	5.38	7.05	7.14	8.42	2.85	0.45	34.63
	DYB									
	YB (t)									
	YB (b)									
	DRG									
	RG (t)									
	RG (b)									
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	0.44	14.68	26.41	38.00	38.72	43.98	14.48	2.21	178.92

Number : 3
Site(s) : 118
Description : Enmore State Forest - stringybark closed forest (SQ4)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.47	0.53		0.07	0.26	0.13			1.5
	SB	0.86	4.13	8.13	5.00	2.33	1.87	0.53	0.13	23.0
	DYB									
	YB			0.06						0.1
	DRG									
	RG									
	DIB									
	IB									
	DGB									
	GB									
	D light	0.07	0.07							0.1
	Light	0.27	0.60	0.47	0.13	0.13	0.34	0.14		2.1
	D/L Ac	0.07								0.1
	D/L Cas	0.07	0.27							0.3
	ALL	1.8	5.7	8.7	5.2	2.7	2.3	0.7	0.1	27.2

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB	62.99	22.44		0.69	1.43	0.44			88.0
	SB	112.25	131.03	119.50	42.82	12.61	6.67	0.90	0.14	425.9
	DYB									
	YB			0.76						0.8
	DRG									
	RG									
	DIB									
	IB									
	DGB									
	GB									
	D light	10.48	2.62							13.0
	Light	38.72	22.90	7.83	1.20	0.65	1.15	0.18		72.6
	D/L Ac	9.41								9.4
	D/L Cas	5.02	8.27							13.3
	ALL	238.8	187.3	128.1	44.7	14.6	8.3	1.1	0.1	623.0

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB	0.82	1.95		0.35	1.54				4.66
	SB (t)		18.22	43.52	29.39	14.57	11.27	1.71	0.31	118.99
	SB (b)		5.21	10.95	6.94	3.30	2.51	0.44	0.08	29.43
	DYB									
	YB (t)			0.62						0.62
	YB (b)			0.08						0.08
	DRG									
	RG (t)									
	RG (b)									
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	0.82	25.38	55.17	36.68	19.41	13.78	2.15	0.39	153.78

Number : 4
Site(s) : 60,61
Description : Boorolong State Forest - stringybark/blackbutt closed forest (SQ4)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.87	0.73	0.37	0.17	0.37	0.23	0.16	0.07	3.0
	SB	0.83	3.00	6.60	10.83	6.47	3.84	0.97	0.16	32.7
	DYB									
	YB									
	DRG									
	RG									
	DIB									
	IB									
	DGB									
	GB									
	D light	0.1								0.1
	Light		0.03	0.07	0.07	0.10	0.06	0.06		0.4
	D/L Ac	0.03								
	D/L Cas									
	ALL	1.8	3.8	7.0	11.1	6.9	4.2	1.2	0.2	36.2

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB	140.09	26.96	5.06	1.28	1.89	0.71	0.26	0.07	176.4
	SB	106.18	96.27	95.33	89.78	34.63	12.84	1.78	0.16	437.0
	DYB									
	YB									
	DRG									
	RG									
	DIB									
	IB									
	DGB									
	GB									
	D light	10.61								10.6
	Light		1.77	0.82	0.61	0.53	0.21	0.11		4.0
	D/L Ac	16.98								17.0
	D/L Cas									
	ALL	273.9	125.0	101.2	91.7	37.0	13.8	2.2	0.2	645.0

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB	1.58	2.84	1.77	0.93	2.11				9.23
	SB (t)		13.18	35.52	63.75	40.46	21.86	3.36	0.36	178.49
	SB (b)		3.60	8.96	16.25	9.70	5.12	0.82	0.09	44.54
	DYB									
	YB (t)									
	YB (b)									
	DRG									
	RG (t)									
	RG (b)									
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	1.58	19.62	46.25	80.93	52.27	26.98	4.18	0.45	232.26

Number : 5
Site(s) : 99
Description : Avondale State Forest - stringybark closed forest (SQ5)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.86	0.91	0.31	0.20	0.14	0.17	0.06		2.7
	SB	0.66	2.26	8.06	7.71	3.83	2.40	0.52		25.4
	DYB	0.06			0.03					0.1
	YB	0.37	0.29	0.34	0.23	0.09	0.03			1.4
	DRG	0.03					0.06			0.1
	RG	0.17	0.14	0.09		0.09				0.5
	DIB									
	IB									
	DGB									
	GB									
	D light	0.09	0.06	0.03						0.2
	Light	0.06	0.23	0.57	0.63	0.49	0.25	0.03		2.2
	D/L Ac		0.03							
	D/L Cas									
	ALL	2.3	3.9	9.4	8.8	4.7	2.9	0.6		32.6

Dens ($s.ha^{-1}$)	DSB	126.25	34.21	4.84	1.63	0.73	0.55	0.09		168.3
	SB	102.30	70.01	117.84	64.77	20.54	8.10	0.98		384.6
	DYB	10.18			0.25					10.4
	YB	30.87	10.72	4.98	1.90	0.48	0.08			49.0
	DRG	8.61					0.16			8.8
	RG	21.73	5.97	1.43		0.50				29.6
	DIB									
	IB									
	DGB									
	GB									
	D light	10.28	2.21	0.36						12.9
	Light	8.21	7.25	8.19	5.15	2.60	0.85	0.05		32.3
	D/L Ac	0.91								0.9
	D/L Cas									
	ALL	319.4	130.4	137.6	73.7	24.9	9.7	1.1		696.8

DWt ($t.ha^{-1}$)	DSB	1.18	2.81	1.25	0.88	0.65				6.77
	SB (t)		10.04	43.07	45.38	24.12	11.80	1.60		136.01
	SB (b)		3.02	11.28	10.80	5.36	2.85	0.36		33.67
	DYB	0.06			0.13					0.19
	YB (t)		2.70	3.16	2.08	0.78	0.19			8.91
	YB (b)		0.49	0.47	0.24	0.09	0.02			1.31
	DRG	0.02								0.02
	RG (t)		0.62	0.44		0.50				1.56
	RG (b)		0.09	0.07		0.11				0.27
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	1.26	19.77	59.74	59.51	31.61	14.86	1.96		188.71

Number : 6
Site(s) : 85
Description : Eastwood State Forest - stringybark closed forest (SQ6)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.20	0.10	0.10	0.02					0.4
	SB	0.34	1.78	4.02	5.14	2.66	1.04	0.12		15.1
	DYB	0.02	0.02	0.02						0.1
	YB	0.16	0.12	0.24	0.32	0.10		0.02		1.0
	DRG	0.04								
	RG	0.14	0.56	0.58	0.30					1.6
	DIB									
	IB									
	DGB									
	GB									
	D light	0.04	0.20	0.10	0.14	0.02				0.5
	Light	0.16	0.46	0.82	0.84	0.50	0.24	0.04		3.1
	D/L Ac	0.42	0.10			0.02				0.5
	D/L Cas									
	ALL	1.5	3.3	5.9	6.8	3.3	1.3	0.2		22.3

Dens ($s.ha^{-1}$)	DSB	26.87	3.69	1.50	0.19					32.3
	SB	37.87	54.07	57.58	42.65	14.63	3.51	0.20		210.5
	DYB	1.40	0.58	0.26						2.2
	YB	15.87	4.83	3.73	2.61	0.53		0.05		27.6
	DRG	7.42								7.4
	RG	11.98	20.35	9.45	2.71					44.5
	DIB									
	IB									
	DGB									
	GB									
	D light	3.14	8.56	1.47	1.26	0.10				14.5
	Light	15.30	13.02	11.97	6.98	2.63	0.90	0.08		50.9
	D/L Ac	102.20	4.17			0.12				106.5
	D/L Cas									
	ALL	222.0	109.3	86.0	56.4	18.0	4.4	0.3		496.4

DWt ($t.ha^{-1}$)	DSB	0.35	0.31	0.39	0.09					1.14
	SB (t)		7.95	21.64	30.37	16.58	5.09	0.34		81.97
	SB (b)		2.25	5.40	7.19	3.72	1.22	0.08		19.86
	DYB	0.04	0.07	0.09						0.20
	YB (t)		1.13	2.23	2.91	0.09		0.12		7.29
	YB (b)		0.20	0.32	0.36	0.10		0.01		0.99
	DRG	0.06								0.06
	RG (t)		2.50	2.99	1.66					7.15
	RG (b)		0.49	0.56	0.32					1.37
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	0.45	14.90	33.62	42.90	21.30	6.31	0.55		120.03

Number : 7
Site(s) : 79,80
Description : Hillgrove Creek State Forest - stringybark closed forest (SQ6)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.10	0.14	0.28	0.03		0.03	0.03		0.6
	SB	0.34	1.17	3.14	4.38	2.10	1.06	0.23	0.07	12.5
	DYB									
	YB		0.14	0.17	0.59	1.59	0.96	0.24		3.7
	DRG			0.07						0.1
	RG	0.07	0.07	0.21	0.14	0.24	0.31	0.03		1.1
	DIB									
	IB									
	DGB									
	GB									
	D light		0.03			0.03	0.07			0.1
	Light	0.07	0.03			0.03	0.03			0.2
	D/L Ac									
	D/L Cas									
	ALL	0.6	1.6	3.9	5.1	4.0	2.5	0.5	0.1	18.3

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB	12.62	4.49	4.41	0.29		0.14	0.05		22.1
	SB	32.76	39.07	44.23	35.99	11.34	3.65	0.47	0.07	167.6
	DYB									
	YB		3.49	2.56	4.69	8.10	3.26	0.41		22.5
	DRG			0.75						0.8
	RG	6.13	3.18	3.38	1.08	1.37	0.90	0.07		16.1
	DIB									
	IB									
	DGB									
	GB									
	D light		0.95			0.20	0.17			1.3
	Light	18.90	1.95			0.15	0.08			21.1
	D/L Ac									
	D/L Cas									
	ALL	70.4	53.1	55.4	42.1	21.2	8.2	1.0	0.1	251.5

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB	0.18	0.45	1.07	0.15					1.85
	SB (t)		5.10	16.90	25.98	13.14	5.30	0.75	0.14	67.31
	SB (b)		1.42	4.55	6.35	3.05	1.26	0.20	0.04	16.87
	DYB									
	YB (t)		1.62	1.60	5.33	14.26	7.20	1.31		31.32
	YB (b)		0.26	0.23	0.68	1.54	0.83	0.14		3.68
	DRG			0.25						0.25
	RG (t)		0.29	1.06	0.77	1.39	1.51	0.15		5.17
	RG (b)		0.06	0.21	0.15	0.26	0.30	0.02		1.00
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	0.18	9.20	25.87	39.41	33.64	16.40	2.57	0.18	127.45

Number : 8
Site(s) : 64,111,112,113,114
Description : Freehold - stringybark closed forest (SQ3-4)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.17	0.40	0.36	0.23	0.22	0.24	0.15	0.02	1.8
	SB	1.54	2.61	3.13	4.12	3.80	3.37	0.58	0.11	19.3
	DYB		0.01							
	YB	0.01	0.03			0.01	0.01			0.1
	DRG									
	RG									
	DIB									
	IB									
	DGB		0.02	0.06	0.02	0.03	0.02	0.01		0.2
	GB	0.33	0.35	0.22	0.20	0.08	0.06	0.02		1.3
	D light	0.05	0.03	0.01	0.02	0.02	0.07	0.06		0.3
	Light	0.71	0.46	0.22	0.30	0.31	0.46	0.21	0.03	2.7
	D/L Ac	0.06	0.06	0.01						0.1
	D/L Cas	0.14	0.20	0.17	0.06	0.02				0.6
	ALL	3.0	4.2	4.2	5.0	4.5	4.2	1.1	0.2	26.4
Dens ($s.ha^{-1}$)	DSB	19.82	13.17	5.54	1.98	1.17	0.83	0.26	0.02	42.8
	SB	217.90	91.50	44.61	33.34	20.21	11.38	1.04	0.10	420.1
	DYB		0.45							0.5
	YB	2.65	1.05			0.06	0.04			3.8
	DRG									
	RG									
	DIB									
	IB									
	DGB		0.96	0.98	0.15	0.18	0.05	0.02		2.3
	GB	47.42	13.08	3.72	1.76	0.46	0.21	0.03		66.7
	D light	7.63	1.07	0.11	0.17	0.10	0.23	0.10		9.4
	Light	117.46	14.77	3.40	2.51	1.62	1.49	0.40	0.03	141.7
	D/L Ac	10.29	2.34	0.12						12.8
	D/L Cas	17.69	6.35	2.74	0.48	0.12				27.4
	ALL	440.9	144.8	61.2	40.4	23.9	14.2	1.9	0.2	727.5
DWt ($t.ha^{-1}$)	DSB	0.43	1.79	1.95	1.43	1.45				7.05
	SB (t)		12.20	18.47	26.77	26.00	21.48	2.18	0.26	107.36
	SB (b)		4.00	4.91	6.62	6.32	5.07	0.54	0.07	27.53
	DYB		0.04							0.04
	YB (t)		0.29			0.09	0.08			0.46
	YB (b)		0.05			0.01	0.01			0.07
	DRG									
	RG (t)									
	RG (b)									
	DIB									
	IB (t)									
	IB (b)									
	DGB		0.07	0.35	0.13	0.19				0.74
	GB (t)		1.54	1.42	1.40	0.57	0.36	0.07		5.36
	GB (b)		0.26	0.26	0.24	0.10	0.06			0.92
	ALL	0.43	20.24	27.36	36.59	34.73	27.06	2.79	0.33	149.53

Number : 9
Site(s) : 29,30
Description : Freehold - stringybark closed forest (SQ5)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.41	0.66	0.45	0.38	0.31	0.03	0.10		2.3
	SB	1.52	4.48	6.31	6.62	3.72	2.62	0.65	0.10	26.0
	DYB	0.07								0.1
	YB	0.10	0.21	0.14	0.07	0.07	0.07			0.7
	DRG									
	RG	0.03	0.07			0.03	0.03			0.2
	DIB									
	IB									
	DGB									
	GB									
	D light	0.03	0.38	0.07	0.31	0.07	0.14			1.0
	Light	0.21	0.14	0.20	0.41	0.17	0.45	0.14		1.7
	D/L Ac									
	D/L Cas									
	ALL	2.4	5.9	7.2	7.8	4.4	3.3	0.9	0.1	32.0

Dens ($s.ha^{-1}$)	DSB	58.36	21.66	7.12	2.90	1.67	0.11	0.17		92.0
	SB	181.00	148.01	94.05	54.80	19.73	8.78	1.23	0.10	507.7
	DYB	4.84								4.8
	YB	20.22	7.62	2.01	0.55	0.33	0.27			31.0
	DRG									
	RG	2.60	3.67			0.15	0.09			6.5
	DIB									
	IB									
	DGB									
	GB									
	D light	6.86	13.26	0.86	2.42	0.42	0.43			24.3
	Light	27.80	4.59	3.49	3.35	0.93	1.47	0.29		41.9
	D/L Ac									
	D/L Cas									
	ALL	301.7	198.8	107.5	64.0	23.2	11.2	1.7	0.1	708.2

DWt ($t.ha^{-1}$)	DSB	0.58	1.91	1.59	1.38	1.46				6.92
	SB (t)		18.44	31.62	36.99	21.98	11.64	1.84	0.19	122.70
	SB (b)		3.78	7.23	7.68	4.32	2.78	0.47	0.06	26.32
	DYB	0.17								0.17
	YB (t)		1.92	1.28	0.62	0.62	0.56			5.00
	YB (b)		0.34	0.19	0.08	0.07	0.06			0.74
	DRG									
	RG (t)		0.25			0.19	0.16			0.60
	RG (b)		0.11			0.06	0.04			0.21
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	0.75	26.75	41.91	46.75	28.70	15.24	2.31	0.25	162.66

Number : 10
Site(s) : 42,43
Description : Freehold - stringybark closed forest (SQ6)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.11	0.79	0.63	0.79	0.05	0.21			2.6
	SB	0.16	0.42	2.11	5.63	7.00	8.11	1.89	0.26	25.6
	DYB	0.05	0.05							0.1
	YB		0.05	0.21	0.11	0.05				0.4
	DRG									
	RG				0.05					0.1
	DIB									
	IB									
	DGB									
	GB									
	D light				0.16					0.2
	Light	0.42	0.21	0.11	0.05	0.21	0.05	0.05		1.1
	D/L Ac	0.05								0.1
	D/L Cas									
	ALL	0.8	1.5	3.1	6.8	7.3	8.4	2.0	0.3	30.2
Dens ($s.ha^{-1}$)	DSB	21.40	25.20	8.91	6.91	0.31	0.73			63.5
	SB	22.63	12.40	30.81	45.59	36.64	26.10	3.45	0.24	177.9
	DYB	3.42	1.07							4.5
	YB		1.45	3.03	0.73	0.26				5.5
	DRG									
	RG				0.40					0.4
	DIB									
	IB									
	DGB									
	GB									
	D light				1.37					1.4
	Light	58.50	10.59	1.75	0.52	1.04	0.18	0.12		72.6
	D/L Ac	9.28								9.3
	D/L Cas									
	ALL	115.3	50.7	44.5	55.5	38.3	27.0	3.6	0.2	335.1
DWt ($t.ha^{-1}$)	DSB	0.09	2.33	2.31	3.13	0.22				8.08
	SB (t)		1.81	10.67	31.46	41.31	34.77	5.20	0.46	125.68
	SB (b)		0.38	2.32	6.58	9.31	8.45	1.31	0.12	28.47
	DYB	0.13	0.21							0.34
	YB (t)		0.50	1.96	0.96	0.47				3.89
	YB (b)		0.08	0.28	0.12	0.05				0.53
	DRG									
	RG (t)				0.30					0.30
	RG (b)				0.06					0.06
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	0.22	5.31	17.54	42.61	51.36	43.22	6.51	0.58	167.35

Number : 11
Site(s) : 91,100
Description : Freehold - stringybark closed forest (SQ6-7)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.20	0.40	0.73	0.47	0.20	0.07			2.0
	SB	1.00	4.00	2.27	1.20	1.47	1.73	0.60	0.13	12.4
	DYB	0.13	0.07							0.2
	YB		0.07	0.27	0.40	0.53	0.33			1.6
	DRG	0.07								0.1
	RG	0.07		0.20						0.3
	DIB									
	IB									
	DGB									
	GB									
	D light	0.07	0.13	0.07	0.07		0.07	0.07		0.5
	Light	0.27	0.87	0.60	0.60	0.07	0.13	0.14		2.7
	D/L Ac	0.07			0.07					0.1
	D/L Cas									
	ALL	1.9	5.6	4.1	2.8	2.3	2.3	0.8	0.1	19.9

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB	29.00	16.57	11.14	3.88	1.01	0.27			61.9
	SB	96.27	138.13	34.91	9.51	7.31	6.00	1.11	0.15	293.4
	DYB	11.67	1.47							13.1
	YB		3.12	3.42	3.33	2.72	1.10			13.6
	DRG	28.06								28.1
	RG	13.26		2.72						16.0
	DIB									
	IB									
	DGB									
	GB									
	D light	4.33	3.73	0.94	0.38		0.26	0.13		9.8
	Light	27.45	31.76	9.01	4.92	0.42	0.48	0.19		74.2
	D/L Ac	4.04			0.46					4.5
	D/L Cas									
	ALL	214.1	194.8	62.1	22.5	11.4	8.1	1.4	0.2	514.6

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB	0.30	1.18	2.88	2.04	0.93				7.33
	SB (t)		17.12	12.02	7.14	9.24	8.68	1.80	0.28	56.28
	SB (b)		4.99	3.04	1.67	2.08	2.08	0.44	0.07	14.37
	DYB	0.29	0.26							0.55
	YB (t)		0.63	2.47	3.65	4.79	2.33			13.87
	YB (b)		0.12	0.34	0.46	0.53	0.26			1.71
	DRG	0.02								0.02
	RG (t)			1.05						1.05
	RG (b)			0.21						0.21
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	0.61	24.30	22.01	14.96	17.57	13.35	2.24	0.35	95.39

Number : 12
Site(s) : 116,117
Description : Styx River State Forest (plateau) - post-logging stringybark/blackbutt open forest (SQ1)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.09	0.18	0.06	0.27	0.15	0.24	0.36	0.24	1.6
	SB	0.60	1.76	2.30	3.00	2.67	3.78	2.27	1.70	18.1
	DYB									
	YB									
	DRG									
	RG									
	DIB									
	IB									
	DGB									
	GB									
	D light		0.03	0.06				0.03	0.03	0.2
	Light	0.15	0.30	0.67	0.36	0.48	0.81	1.27	0.45	4.5
	D/L Ac	0.30								0.3
	D/L Cas	0.09	0.39	0.12						0.6
	ALL	1.2	2.7	3.2	3.6	3.3	4.9	4.0	2.4	25.3

Dens ($s.ha^{-1}$)	DSB	21.95	6.17	1.12	2.38	0.83	0.83	0.65	0.21	34.1
	SB	82.32	60.11	33.53	24.48	13.99	12.50	4.02	1.37	232.3
	DYB									
	YB									
	DRG									
	RG									
	DIB									
	IB									
	DGB									
	GB									
	D light		1.51	1.09				0.05	0.03	2.7
	Light	24.37	9.70	8.85	2.92	2.57	2.51	2.13	0.45	53.5
	D/L Ac	62.48								62.5
	D/L Cas	9.20	14.18	20.8						25.5
	ALL	200.3	91.7	46.7	29.8	17.4	15.8	6.8	2.1	410.6

DWt ($t.ha^{-1}$)	DSB	0.11	0.87	0.72	1.39	1.04				4.13
	SB (t)		8.78	14.33	20.60	19.36	25.18	8.91	3.62	100.78
	SB (b)		3.01	4.03	5.25	4.66	5.93	2.17	0.93	25.98
	DYB									
	YB (t)									
	YB (b)									
	DRG									
	RG (t)									
	RG (b)									
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	0.11	12.66	19.08	27.24	25.06	31.11	11.08	4.55	130.89

Number : 13
Site(s) : 41,45,65,74,75,80,94,98,102,104
Description : Freehold (various locations) - stringybark open forest (SQ5-6-7)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.35	0.28	0.31	0.28	0.26	0.21	0.08		1.8
	SB	1.12	2.48	2.67	2.55	2.21	2.59	0.95	0.07	14.6
	DYB	0.03	0.03	0.03	0.01	0.01		0.02		0.1
	YB	0.07	0.25	0.16	0.17	0.15	0.15	0.03		1.0
	DRG			0.01		0.01				
	RG	0.10	0.16	0.06	0.05	0.04	0.02	0.01		0.4
	DIB									
	IB									
	DGB									
	GB	0.01	0.01	0.01			0.01	0.01		0.1
	D light	0.04	0.06	0.03	0.01	0.02	0.02			0.2
	Light	0.02	0.19	0.21	0.18	0.14	0.13	0.10	0.03	1.0
	D/L Ac	0.01	0.03	0.01						0.1
	D/L Cas									
	ALL	1.8	3.5	3.5	3.3	2.8	3.1	1.2	0.1	19.3

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB	49.80	10.22	4.48	2.19	1.35	0.71	0.15		68.9
	SB	141.20	85.01	39.91	20.97	11.48	8.49	1.74	0.07	308.9
	DYB	3.91	0.94	0.50	0.04	0.06		0.02		5.5
	YB	9.11	9.06	2.46	1.31	0.77	0.48	0.04		23.2
	DRG			0.07		0.03				0.1
	RG	19.08	6.20	0.98	0.38	0.22	0.06	0.01		26.9
	DIB									
	IB									
	DGB									
	GB	0.60	0.25	0.21			0.02	0.01		1.1
	D light	6.59	1.92	0.51	0.05	0.09	0.07			9.2
	Light	2.48	6.05	3.20	1.36	0.79	0.42	0.19	0.02	14.5
	D/L Ac	1.55	1.30	0.18						2.9
	D/L Cas									
	ALL	234.3	120.9	52.5	26.3	14.8	10.2	2.1	0.1	461.2

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB	0.52	0.89	1.22	1.22	1.18				5.03
	SB (t)		10.67	14.37	15.04	13.83	12.42	2.85	0.14	69.32
	SB (b)		3.06	3.74	3.58	3.11	2.99	0.72	0.03	17.23
	DYB	0.07	0.10	0.12	0.03	0.06				0.38
	YB (t)		2.34	1.48	1.56	1.33	1.07	0.13		7.91
	YB (b)		0.41	0.21	0.19	0.15	0.11	0.01		1.08
	DRG									
	RG (t)		0.69	0.33	0.26	0.23	0.09	0.03		1.63
	RG (b)		0.13	0.06	0.04	0.04	0.02			0.29
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)		0.03	0.07			0.04	0.02	0.01	0.17
	GB (b)		0.02							0.02
	ALL	0.59	18.34	21.60	21.92	19.93	16.74	3.76	0.18	103.06

Number : 14
Site(s) : 69,87,105,106
Description : Travelling stock reserve (various locations) - stringybark woodland (mainly SQ6)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB							0.04		
	SB		0.38	0.01	0.20	2.15	0.10			2.8
	DYB							0.01		
	YB	0.01	0.01	0.02	0.01	0.02	0.06	0.02		0.2
	DRG									
	RG				0.04	0.01				0.1
	DIB									
	IB									
	DGB									
	GB									
	D light									
	Light									
	D/L Ac									
	D/L Cas									
	ALL		0.4		0.2	2.2	0.2	0.1		3.1

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB							0.08		0.1
	SB	0.31	10.18	0.17	1.65	9.79	0.35			22.5
	DYB							0.01		
	YB	1.35	0.38	0.23	0.07	0.11	0.14	0.05		2.3
	DRG									
	RG	0.07	0.02		0.27	0.04				0.4
	DIB									
	IB									
	DGB									
	GB									
	D light									
	Light		0.18	0.01	0.01					0.2
	D/L Ac									
	D/L Cas									
	ALL	1.7	10.8	0.4	2.0	10.0	0.5	0.1		25.5

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB									
	SB (t)		1.74	0.07	1.17	13.74	0.51			17.23
	SB (b)		0.48	0.02	0.28	3.07	0.12			3.97
	DYB									
	YB (t)		0.10	0.14	0.09	0.21	0.36	0.14		1.04
	YB (b)		0.02	0.02	0.01	0.02	0.04	0.02		0.13
	DRG		0.01							0.01
	RG (t)				0.23	0.04				0.27
	RG (b)				0.04	0.02				0.06
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL		2.35	0.25	1.82	17.10	1.03	0.16		22.71

Number : 15

Site(s) : 3,5,8,9,10,11,13,16,17,18,19,20

Description : Travelling stock reserve and freehold (various western locations) - ironbark closed and open forest (SQ6-7)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.02	0.08	0.06	0.09	0.03	0.03	0.02		0.3
	SB	0.18	0.42	0.29	0.39	0.54	0.57	0.16	0.02	2.6
	DYB			0.01						
	YB		0.05	0.08	0.05	0.01	0.04	0.01		0.2
	DRG	0.01	0.02							
	RG	0.11	0.21	0.34	0.18	0.07	0.15	0.01		1.1
	DIB	0.07	0.06	0.05	0.04	0.04	0.09	0.09	0.01	0.5
	IB	0.37	0.99	1.53	1.65	1.51	1.71	0.90	0.24	8.9
	DGB	0.01	0.02	0.01	0.01	0.02	0.01			0.1
	GB	0.21	0.37	0.32	0.31	0.24	0.40	0.24	0.05	2.2
	D light			0.01		0.01	0.01			
	Light	0.05	0.07	0.05	0.05	0.03	0.05			0.3
	D/L Ac									
	D/L Cas									
	ALL	1.0	2.3	2.8	2.8	2.5	3.1	1.4	0.3	16.2

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB	1.72	2.91	0.91	0.74	0.18	0.08	0.04		6.6
	SB	23.70	14.29	4.31	3.11	2.82	1.88	0.27	0.02	50.4
	DYB		0.09	0.13						0.2
	YB	0.40	1.64	1.19	0.39	0.07	0.13	0.03		3.8
	DRG	1.39	0.63							2.0
	RG	11.82	6.92	5.24	1.57	0.36	0.15	0.02		26.1
	DIB	6.69	2.33	0.62	0.31	0.20	0.28	0.13	0.01	10.6
	IB	46.43	33.47	22.52	13.30	7.84	5.62	1.58	0.21	131.0
	DGB	1.45	0.68	0.18	0.06	0.09	0.04			2.5
	GB	29.39	12.66	4.87	2.44	1.22	1.32	0.43	0.05	52.4
	D light			0.22	0.04	0.05	0.05			0.4
	Light	4.82	2.57	0.74	0.41	0.18	0.16	0.02		8.9
	D/L Ac									
	D/L Cas									
	ALL	127.8	78.2	40.9	22.4	13.0	9.7	2.6	0.3	294.9

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB	0.04	0.25	0.25	0.39	0.16				1.09
	SB (t)		1.78	1.52	2.30	3.38	2.73	0.40	0.10	12.21
	SB (b)		0.50	0.41	0.55	0.77	0.66	0.12		3.01
	DYB		0.02	0.04						0.06
	YB (t)		0.37	0.70	0.45	0.13	0.34	0.09		2.08
	YB (b)		0.08	0.11	0.07	0.02	0.04	0.01		0.33
	DRG	0.03	0.05							0.08
	RG (t)		0.98	1.75	1.00	0.39	0.25	0.04	0.02	4.43
	RG (b)		0.19	0.30	0.17	0.06	0.06			0.78
	DIB	0.37	0.41	0.32	0.26	0.26				1.62
	IB (t)		7.26	11.78	12.94	11.91	11.66	4.51	0.96	61.02
	IB (b)		3.89	6.26	6.72	6.15	6.26	2.42	0.51	32.21
	DGB	0.02	0.07	0.07	0.05	0.11				0.32
	GB (t)		1.85	2.06	2.10	1.69	2.35	0.93	0.13	11.11
	GB (b)		0.32	0.30	0.41	0.34	0.41	0.16	0.02	1.96
	ALL	0.46	18.02	25.87	27.41	25.37	24.76	8.68	1.74	132.31

Number : 16
Site(s) : 26,27,44
Description : Freehold - box/gum closed and open forest (SQ6-7)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.03	0.11	0.03	0.03		0.14			0.3
	SB	0.09	0.34	0.57	0.83	0.94	0.63	0.35	0.09	3.8
	DYB	0.03			0.03					0.1
	YB	0.37	0.63	0.57	0.69	0.23	0.32	0.06		2.9
	DRG	0.09	0.09	0.06						0.2
	RG	0.57	1.09	1.43	1.46	1.00	1.20	0.60		7.3
	DIB									
	IB									
	DGB									
	GB									
	D light	0.03	0.03	0.06	0.11	0.06	0.06	0.03		0.4
	Light	0.11	0.17	0.29	0.69	0.71	0.89	0.26	0.03	3.2
	D/L Ac									
	D/L Cas									
	ALL	1.3	2.5	3.0	3.9	2.9	3.2	1.3	0.1	18.2

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB	2.53	4.27	0.36	0.20		0.51			7.9
	SB	9.22	10.07	8.24	6.67	5.07	2.06	0.64	0.08	42.0
	DYB	2.15			0.20					2.4
	YB	59.93	22.63	8.14	5.58	1.13	1.05	0.10		98.6
	DRG	12.62	1.45	0.59						14.7
	RG	112.94	35.13	20.43	12.28	5.49	3.80	1.07		191.1
	DIB									
	IB									
	DGB									
	GB									
	D light	4.49	0.79	0.82	1.02	0.32	0.15	0.04		7.6
	Light	11.93	5.73	4.19	5.72	3.80	2.83	0.49	0.03	34.7
	D/L Ac									
	D/L Cas									
	ALL	215.8	80.1	42.8	31.7	15.8	10.4	2.3	0.1	399.0

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB	0.06	0.35	0.12	0.13					0.66
	SB (t)		1.55	3.07	4.91	5.89	3.01	1.05	0.16	19.64
	SB (b)		0.44	0.77	1.15	1.33	0.73	0.26	0.04	4.72
	DYB	0.07			0.14					0.21
	YB (t)		5.90	5.29	6.25	2.05	2.33	0.31		22.13
	YB (b)		1.04	0.75	0.78	0.23	0.26	0.04		3.10
	DRG	0.16	0.09	0.20	0.20					0.65
	RG (t)		4.96	7.49	8.11	5.78	6.12	2.43		34.89
	RG (b)		0.94	1.40	1.54	1.10	1.14	0.47		6.59
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	0.29	15.27	19.09	23.21	16.38	13.59	4.56	0.20	92.59

Number : 17
Site(s) : 1,4,22,23,25,32,38,39,40,51,68,82,107,123
Description : Travelling stock reserve (various locations) - box/gum woodland (SQ5-6-7)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB									
	SB				0.01	0.01	0.02	0.05		0.1
	DYB							0.01		
	YB	0.06	0.48			0.07	0.23	0.10		0.9
	DRG						0.01			
	RG	0.02	0.15	0.26	0.08	0.15	0.24	0.27	0.08	1.3
	DIB									
	IB									
	DGB									
	GB						0.06	0.04		0.1
	D light			0.03	0.01					
	Light	0.05	0.59	0.19	0.03	0.29	0.02	0.19	0.49	1.9
	D/L Ac									
	D/L Cas									
	ALL	0.1	1.2	0.5	0.1	0.5	0.6	0.7	0.6	4.3

Dens ($s.ha^{-1}$)	DSB									
	SB		0.11		0.07	0.05	0.05	0.10		0.4
	DYB							0.01		
	YB	6.99	22.37	0.05	0.01	0.19	0.61	0.17		30.4
	DRG						0.02			
	RG	1.72	9.69	3.93	0.64	0.77	0.63	0.46		17.8
	DIB									
	IB									
	DGB									
	GB	0.44	0.03				0.14	0.08		0.7
	D light			0.40	0.09		0.01			0.5
	Light	4.71	23.26	1.52	0.21	1.36	0.07	0.28	0.47	31.9
	D/L Ac									
	D/L Cas									
	ALL	13.9	55.4	5.9	1.0	2.4	1.5	1.1	0.5	81.7

DWt ($t.ha^{-1}$)	DSB									
	SB (t)		0.01		0.05	0.04	0.07	0.15		0.32
	SB (b)				0.01	0.01	0.02	0.04		0.08
	DYB									
	YB (t)		4.41	0.04	0.02	0.30	1.46	0.52		6.75
	YB (b)		0.83	0.01		0.03	0.16	0.06		1.09
	DRG									
	RG (t)		1.43	1.31	0.44	0.85	1.10	1.05	0.25	6.43
	RG (b)		0.26	0.24	0.09	0.17	0.20	0.19	0.06	1.21
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)		0.01				0.29	0.18		0.48
	GB (b)						0.02	0.01		0.03
	ALL		6.95	1.60	0.61	1.40	3.32	2.20	0.31	16.39

Number : 18
Site(s) : 24,37,46,47,48,49,54,55,62,70,71,72,73,81,88,93
Description : Travelling stock reserve (various location) - box/gum and 'light' scattered trees (SQ4-5-6-7)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB									
	SB									
	DYB			0.05						0.1
	YB					0.01	0.01			
	DRG									
	RG				0.01		0.12			0.1
	DIB									
	IB									
	DGB									
	GB									
	D light		0.03	0.04	0.03	0.14	0.12	0.07	0.02	0.5
	Light	0.01	0.04	0.03	0.01	0.01	0.03	0.17	0.03	0.3
	D/L Ac									
	D/L Cas									
	ALL		0.1	0.1	0.1	0.1	0.3	0.2	0.1	1.0

Dens ($s.ha^{-1}$)	DSB									
	SB									
	DYB			0.53						0.5
	YB	0.01			0.01	0.03	0.02			0.1
	DRG									
	RG		0.11	0.03	0.03	0.03	0.32	0.01		0.6
	DIB									
	IB									
	DGB									
	GB									
	D light	0.11	0.81	0.53	0.31	0.75	0.37	0.13	0.02	3.0
	Light	0.89	1.54	0.42	0.05	0.05	0.11	0.33	0.03	3.4
	D/L Ac									
	D/L Cas									
	ALL	1.0	2.5	1.5	0.4	0.8	0.8	0.5	0.1	7.6

DWt ($t.ha^{-1}$)	DSB									
	SB (t)									
	SB (b)									
	DYB			0.87						0.87
	YB (t)				0.06	0.25	0.22			0.53
	YB (b)				0.01	0.03	0.03			0.07
	DRG									
	RG (t)		0.04	0.04	0.11	0.10	2.23	0.07		2.59
	RG (b)				0.02	0.02	0.41	0.02		0.47
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL		0.04	0.91	0.20	0.40	2.89	0.09		4.53

Number : 19
Site(s) : 90,92
Description : Freehold - 'light' open forest (SQ6-7)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB	0.22	0.11	0.17	0.06					0.6
	SB	0.11	1.06	1.39	1.00	0.83	0.78	0.06		5.2
	DYB						0.12			0.1
	YB	0.17	0.17	0.17	0.06	0.06	0.33	0.11		1.1
	DRG		0.06				0.06			0.1
	RG		0.11			0.06	0.06			0.2
	DIB									
	IB									
	DGB									
	GB									
	D light	0.22	0.17	0.06	0.28	0.17	0.34		0.06	1.3
	Light	0.67	2.56	3.11	2.56	1.89	2.11	0.55	0.22	13.7
	D/L Ac		0.06		0.06					0.1
	D/L Cas				0.06					0.1
	ALL	1.4	4.3	4.9	4.1	3.0	3.8	0.7	0.3	22.5

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB	24.36	4.37	3.06	0.53					32.3
	SB	11.33	35.44	20.18	8.39	4.38	2.50	0.07		82.3
	DYB						0.33			0.3
	YB	27.93	7.11	2.37	0.38	0.25	1.23	0.23		39.5
	DRG		1.60				0.17			1.8
	RG		2.64			0.27	0.19			3.1
	DIB									
	IB									
	DGB									
	GB									
	D light	30.73	4.29	0.63	2.31	0.87	1.09		0.06	40.0
	Light	59.37	80.16	45.92	20.91	9.72	6.94	1.07	0.23	224.3
	D/L Ac		1.28		0.49					1.8
	D/L Cas				0.58					0.6
	ALL	153.7	136.9	72.2	33.6	15.5	12.4	1.4	0.3	426.0

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB	0.38	0.34	0.63	0.24					1.59
	SB (t)		4.53	7.45	5.92	5.21	3.65	0.12		26.88
	SB (b)		1.33	1.89	1.44	1.20	0.87	0.03		6.76
	DYB									
	YB (t)		1.56	1.54	0.50	0.50	2.61	0.65		7.36
	YB (b)		0.29	0.22	0.06	0.05	0.27	0.08		0.97
	DRG		0.17							0.17
	RG (t)		0.54			0.33	0.29			1.16
	RG (b)		0.11			0.06	0.06			0.23
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL	0.38	8.87	11.73	8.16	7.35	7.75	0.88		45.12

Number : 20
Site(s) : 36,53,56,57,58,59,96,97
Description : Travelling stock reserve (various locations) - 'light' woodland (SQ3-4-5-6)

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB SB									
	DYB YB									
	DRG RG									
	DIB IB									
	DGB GB									
	D light	0.01	0.01	0.01	0.02	0.81	0.14	0.01		1.0
	Light	0.36	1.30	0.11	0.39	0.30	0.21	0.23		2.9
	D/L Ac									
	D/L Cas									
	ALL	0.4	1.3	0.1	0.4	1.1	0.4	0.2		3.9

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
Dens ($s.ha^{-1}$)	DSB SB									
	DYB YB									
	DRG RG									
	DIB IB									
	DGB GB									
	D light	0.68	0.36	0.19	0.15	4.18	0.47	0.02		6.1
	Light	34.69	34.98	1.62	2.88	1.49	0.65	0.41		76.6
	D/L Ac	0.04	0.02							0.1
	D/L Cas									
	ALL	35.4	35.4	1.8	3.0	5.7	1.1	0.4		82.8

		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
DWt ($t.ha^{-1}$)	DSB SB (t) SB (b)									
	DYB YB (t) YB (b)									
	DRG RG (t) RG (b)									
	DIB IB (t) IB (b)									
	DGB GB (t) GB (b)									
	ALL									

Number : 21
Site(s) : 50,86,89
Description : Travelling stock reserve - isolated 'light' stand (SQ6).

		Diameter class (overbark, cm)								
		5-15	15-25	25-35	35-45	45-55	55-75	75-105	105 +	TOT
BA ($m^2.ha^{-1}$)	DSB									
	SB									
	DYB		0.004			0.014	0.002			0.02
	YB							0.013		0.01
	DRG						0.003	0.032	0.004	0.04
	RG		0.001							
	DIB									
	IB									
	DGB									
	GB									
	D light		0.009	0.022	0.017	0.085	0.042	0.025	0.013	0.22
	Light		0.015	0.001	0.001	0.010		0.002		0.03
	D/L Ac									
	D/L Cas									
	ALL		0.03	0.02	0.02	0.11	0.05	0.07	0.02	0.32

Dens ($s.ha^{-1}$)	DSB									
	SB									
	DYB	0.025	0.112			0.068	0.007			0.21
	YB							0.029		0.03
	DRG						0.006	0.049	0.005	0.06
	RG		0.030							0.03
	DIB									
	IB									
	DGB									
	GB									
	D light		0.299	0.345	0.137	0.492	0.113	0.049	0.014	1.45
	Light		0.388	0.013	0.009	0.028		0.003		0.44
	D/L Ac									
	D/L Cas									
	ALL	0.03	0.83	0.36	0.14	0.59	0.12	0.13	0.02	2.22

DWt ($t.ha^{-1}$)	DSB									
	SB (t)									
	SB (b)									
	DYB		0.01			0.07				0.08
	YB (t)							0.08		0.08
	YB (b)							0.01		0.01
	DRG									
	RG (t)		0.01							0.01
	RG (b)									
	DIB									
	IB (t)									
	IB (b)									
	DGB									
	GB (t)									
	GB (b)									
	ALL		0.02			0.07		0.09		0.18

Appendix XXIII. Site summary data for immature trees

Site	Area (ha)	Sdlngs	Sdlngs ha^{-1}	Juvs	Juvs ha^{-1}	Saplngs	Saplngs ha^{-1}	AC.juvs ha^{-1}	AC.saplngs ha^{-1}
1	0.4					28	70		0
2	0.4					26	65		10
3	0.18	23	128	5	28	9	50	83	78
4	0.4					17	43		0
5	0.5	31	62	6	12	11	22		2
6	0.4					29	73		0
7	0.4					119	298		0
8	0.15	31	207	10	67	11	73	27	0
9	0.16	31	194	14	88	7	44	113	113
10	0.18	37	206	16	89	8	44	178	61
11	0.19	14	74	1	5	2	11	5	0
12	0.4					49	123		8
13	0.14	19	136	8	57	3	21	21	7
14	0.4					36	90		25
15	0.4					7	18		0
16	0.15	0	0	0	0	0	0	0	0
17	0.18	8	44	5	28	13	72	0	0
18	0.14	6	43	17	121	10	71	7	43
19	0.23	9	39	8	35	6	26	4	13
20	0.18	4	22	9	50	11	61	6	11
21	0.4					10	25		5
22	0.4					36	90		0
23	0.4					21	53		58
24	0.4					4	10		0
25	0.4					17	43		0
28	0.4					5	13		0
31	0.4					10	25		0
32	0.4					10	25		0
33	0.4					8	20		0
34	0.4					42	105		138
35	0.4					36	90		10
36	0.4					15	38		0
37	0.4					10	25		0
38	0.4					67	168		0
39	0.4					52	130		0
40	0.4					60	150		0
46	0.4					0	0		0
47	0.4					0	0		0
48	0.4					0	0		0
49	0.4					0	0		0
50	0.4					0	0		0
51	0.4					20	50		10
52	0.4					23	58		0
53	0.4					16	40		0
54	0.4					0	0		0
55	0.4					33	83		0
56	0.4					13	33		0
57	0.4					58	145		0
58	0.4					8	20		18
59	0.4					12	30		0

Site	Area (ha)	Sdlngs	Sdlngs ha^{-1}	Juvs	Juvs ha^{-1}	Saplngs	Saplngs ha^{-1}	AC.juvs ha^{-1}	AC.saplngs ha^{-1}
62	0.4					43	108		0
63	0.4					210	525		8
64	0.4	370	925	176	440	36	90	8	3
65	0.87	193	222	99	114	57	66	0	0
66	0.4					77	193		0
67	0.4					162	405		5
68	0.4					117	293		0
69	0.4					46	115		0
70	0.4					7	18		0
71	0.4					46	115		0
72	0.4					47	118		0
73	0.4					6	15		0
74	0.4			20	50	8	20	5	0
75	0.06			7	117	3	50	0	0
76	0.4					23	58		0
77	0.4					11	28		30
78	0.4					39	98		0
79	0.29	247	852	50	172	19	66	41	38
80	0.08	20	250	4	50	6	75	0	0
81	0.4					1	3		0
82	0.4					46	115		215
83	0.4					2	5		50
84	0.4					15	38		20
85	0.5	426	852	71	41	142	82	20	56
86	0.4					0	0		0
87	0.4					15	38		0
88	0.4					42	105		0
89	0.4					0	0		0
93	0.4					0	0		0
95	0.4					143	358		0
96	0.4					65	163		33
97	0.4					224	560		0
98	0.08			35	438	24	300	13	0
99	0.35	179	511	45	129	32	91	0	0
100	0.06			28	467	7	117	17	17
101	0.4					48	120		0
102	0.08			13	163	4	50	0	0
103	0.4					24	60		0
104	0.05			0	0	1	20	0	0
105	0.4					9	23		0
106	0.4					35	88		0
107	0.4					190	475		0
108	0.4					144	360		0
109	0.4					18	45		3
110	0.4					21	53		0
123	0.4					40	100		0

Sdlings = Seedlings (0-0.5 m)
Juvs = Juveniles (0.5-2.0 m)
Saplngs = Sapling (2.0-5.0 m)
AC = Acacias

Appendix XXIV. Juvenile and sapling count for each species at each site

		SB		YB		RG		IB		GB		AB		WG		NEP		ANG		SG		BS		Other		Ac.Spp.	
Site	Area	juv	sapl	juv	sap	juv	sap	juv	sapl	juv	sap	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl
1	0.4						3				24								1								
2	0.4		12						7		5								2								4
3	0.18	2					1	2	4	1	4															15	14
4	0.4				9		7																		1		
5	0.5					4	5	2			4								2								1
6	0.4				15		4				10																
7	0.4		2		2		21				64														30		
8	0.15	2	5					7	4	1	2															4	
9	0.16	1	1			8	3	2	1	2	2							1								18	18
10	0.18	5	2					7	3	4	3															32	11
11	0.19									1	2															1	
12	0.4				5		16				26								2								3
13	0.14	3	1			3				2	2															3	1
14	0.4								13																23		10
15	0.4						5																		2		
16	0.15																										
17	0.18					1		1	4	3	3														6		
18	0.14	4	3			1	2			12	5															1	6
19	0.23		3			1		5	3	2																1	3
20	0.18					1		4	9	4	2															1	2
21	0.4										10																2
22	0.4						36																				
23	0.4						7						5						9								23
24	0.4						3																		1		
25	0.4				2		14												1								
28	0.4						5																				
31	0.4				1		8						1														
32	0.4		1		1		8																				
33	0.4		3																4						1		
34	0.4		18		5		14												4						1		55
35	0.4		2		17		9										6								2		4
36	0.4						1										14										
37	0.4						2										8										

		SB		YB		RG		IB		GB		AB		WG		NEP		ANG		SG		BS		Other		Ac.Spp.	
Site	Area	juv	sapl	juv	sap	juv	sap	juv	sapl	juv	sap	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl
38	0.4				60		7																				
39	0.4				25		27																				
40	0.4				15		45																				
46	0.4																										
47	0.4																										
48	0.4																										
49	0.4																										
50	0.4																										
51	0.4						11						8												1		4
52	0.4						2								15				3						3		
53	0.4																16										
54	0.4																										
55	0.4				5		11								1		16										
56	0.4																10						3				
57	0.4																37				17		4				
58	0.4														4						4						7
59	0.4																12										
62	0.4																5								38		
63	0.4		54		133		23																				3
64	0.4	174	32										3	2	1											3	1
65	0.87	87	57									6		2		4											
66	0.4		52		7		7								11												
67	0.4		35		116		9						1												1		2
68	0.4						32								17				68								
69	0.4		2		30		12												2								
70	0.4																7										
71	0.4																46										
72	0.4						35										12										
73	0.4						1								5												
74	0.4	11	5			8	3					1														2	
75	0.06	3	1	2		2	1						1														
76	0.4		9		3		8								3												
77	0.4		3				7						1														12

		SB		YB		RG		IB		GB		AB		WG		NEP		ANG		SG		BS		Other		Ac.Spp.	
Site	Area	juv	sapl	juv	sap	juv	sap	juv	sapl	juv	sap	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl	juv	sapl
78	0.4		11		8		20																				
79	0.29	15	11	24	4	8	4					3														12	11
80	0.08	4	3		1		2																				
81	0.4																								1		
82	0.4				18		22										5								1		86
83	0.4				2																						20
84	0.4		4				3						5		3												8
85	0.5	31	11	5	3	3	7					1		18	6									13	14	10	28
86	0.4																										
87	0.4		1		14																						
88	0.4				28		4										10										
89	0.4																										
93	0.4																										
95	0.4																55				78		10				
96	0.4														20						11		34				13
97	0.4																6				131		56		31		
98	0.08	34	24			1																				1	
99	0.35	29	18	5	3	11	7						1		3												
100	0.06	16	2	10	4									1	1									1		1	1
101	0.4		22		1										11		12						1		1		
102	0.08	12	3	1											1												
103	0.4		9		7										2				4						2		
104	0.05		1																								
105	0.4		1		1		6												1								
106	0.4		1		19		15																				
107	0.4						31								3		3								153		
108	0.4		39		56		42						6												1		
109	0.4		3		15																						1
110	0.4														1		13				6				1		
123	0.4						34						2						4								
	34.4	433	467	47	635	52	612	30	48	32	168	11	34	23	108	4	293	1	107	0	247	0	108	14	315	105	354

SB = stringybark (various spp.) ; YB = yellow box *E. melliodora* ; RG = red gum *E. blakelyi* ; IB = ironbark *E. sideroxylon* ; GB = grey (& white) box *E. moluccana* & *E. albens* ; AB = apple box *E. bridgesiana* ; WG = white (& mountain) gum *E. viminalis* & *E. dalrympleana*; NEP = New England peppermint *E. nova-anglica* ; ANG = *Angophora floribunda*; SG = snow gum *E. pauciflora* ; BS = black sallee *E. stellulata* ; Ac = *Acacia* spp. ; (juv = juvenile; sapl = sapling.)

Appendix XXV. Mann-Whitney and Kruskal-Wallis tests explaining the effect of land tenure, cover, or tree class on the density of natural regeneration in southern New England.

			Statistical parameters						
Test	Dependent variable (density)	Independent variable	No. plots	Mean (n.ha^{-1})	Rank sum	DF	Mann-Whitney *U*	Kruskal-Wallis *H*	*P*
1	eucalypt seedlings in closed forest	freehold	54	696 ± 130	4423.0	2	-	39.718	***
		state forest	107	796 ± 159	11248.5				
		TSR	18	44 ± 39	438.5				
2	eucalypt seedlings in open forest	freehold	231	145 ± 19	34380.0	1	7584.0	-	*ns*
		TSR	66	117 ± 24	9873.0				
3	eucalypt seedlings on freehold land	closed forest	54	696 ± 130	10523.5	1	9038.5	-	***
		open forest	231	154 ± 19	30231.5				
4	eucalypt seedlings on TSR	closed forest	18	44 ± 39	567.5	1	396.5	-	**
		open forest	66	117 ± 24	3002.5				
5	eucalypt juveniles in closed forest	freehold	60	368 ± 74	7404.5	2	-	28.454	***
		state forest	114	146 ± 25	10100.5				
		TSR	18	28 ± 18	1023.0				
5a	acacia juveniles in closed forest	freehold	60	8 ± 4	5715.5	2	-	2.229	*ns*
		state forest	114	19 ± 6	11210.5				
		TSR	18	0	1602.0				
6	eucalypt juveniles in open forest	freehold	266	82 ± 13	44050.5	1	8539.5	-	*ns*
		TSR	66	55 ± 14	11227.5				
6a	acacia juveniles in open forest	freehold	266	15 ± 5	42933.0	1	7422.0	-	***
		TSR	66	56 ± 22	12345.0				
7	eucalypt juveniles on freehold land	closed forest	60	368 ± 74	14075.0	1	12245.0	-	***
		open forest	266	82 ± 13	39226.0				
7a	acacia juveniles on freehold land	closed forest	60	8 ± 4	9883.5	1	8053.5	-	*ns*
		open forest	266	15 ± 5	43417.5				
8	eucalypt juveniles on TSR	closed forest	18	28 ± 8	660.5	1	489.5	-	*ns*
		open forest	66	55 ± 14	2909.5				
8a	acacia juveniles on TSR	closed forest	18	0	639.0	1	468.0	-	**
		open forest	66	56 ± 22	2931.0				
9	eucalypt saplings in closed forest	freehold	60	88 ± 16	6818.5	2	-	4.006	*ns*
		state forest	126	76 ± 16	12912.5				
		TSR	30	108 ± 27	3705.0				
9a	acacia saplings in closed forest	freehold	60	13 ± 9	6047.5	2	-	9.210	**
		state forest	126	33 ± 8	14486.5				
		TSR	30	1 ± 1	2902.0				
10	eucalypt saplings in open forest	freehold	266	53 ± 8	47671.5	2	-	48.143	***
		state forest	8	63 ± 18	2204.5				
		TSR	134	97 ± 13	33560.0				
10a	acacia saplings in open forest	freehold	266	6 ± 2	52016.0	2	-	21.050	***
		state forest	8	15 ± 10	1904.0				
		TSR	134	31 ± 13	29516.0				
11	eucalypt saplings on freehold land	closed forest	60	88 ± 16	11722.0	1	9892.0	-	***
		open forest	266	53 ± 8	41579.0				
11a	acacia saplings on freehold land	closed forest	60	13 ± 9	10070.5	1	8240.5	-	*ns*
		open forest	266	6 ± 2	43230.5				
12	eucalypt saplings in state forest	closed forest	126	76 ± 16	8373.0	1	372.0	-	*ns*
		open forest	8	63 ± 18	672.0				

ns (P > 0.5) not significant
* (0.01< P ≤ 0.5)
** (0.001< P ≤ 0.01)
*** (P ≤ 0.001)

			Statistical parameters						
Test	Dependent variable (density)	Independent variable	No. plots	Mean ($n.ha^{-1}$)	Rank sum	DF	Mann-Whitney *U*	Kruskal-Wallis *H*	*P*
12a	acacia saplings in state forest	closed forest	126	33 ± 8	8496.0	1	495.0	-	*ns*
		open forest	8	15 ± 10	549.0				
13	eucalypt saplings on TSR	closed forest	30	108 ± 27	5508.0	4	-	45.746	***
		open forest	134	97 ± 13	23648.0				
		woodland	112	115 ± 13	23910.0				
		scattered trees	64	37 ± 10	8354.0				
		isolated trees	12	0	708.0				
13a	acacia saplings on TSR	closed forest	30	1 ± 1	4916.0	4	-	15.398	**
		open forest	134	31 ± 13	24918.0				
		woodland	112	13 ± 7	20286.0				
		scattered trees	64	0	10112.0				
		isolated trees	12	0	1896.0				
14	eucalypts in closed forest on freehold land	seedlings	54	696 ± 130	5750.0	2	-	28.270	***
		juveniles	60	368 ± 74	5832.0				
		saplings	60	88 ± 16	3643.0				
15	eucalypts in closed forest in state forest	seedlings	107	796 ± 59	28988.0	2	-	158.367	***
		juveniles	114	146 ± 25	16298.0				
		saplings	126	76 ± 16	15092.0				
16	eucalypts in closed forest on TSR	seedlings	18	44 ± 39	471.5	2	-	13.033	**
		juveniles	18	28 ± 14	497.5				
		saplings	30	108 ± 27	1242.5				
17	eucalypts in open forest on freehold land	seedlings	231	145 ± 19	99513.5	2	-	27.768	***
		juveniles	266	82 ± 13	99625.0				
		saplings	266	53 ± 8	92327.5				
18	eucalypts in open forest on TSR	seedlings	66	117 ± 24	8886.5	2	-	7.613	*
		juveniles	66	55 ± 14	7467.5				
		saplings	134	97 ± 13	19157.0				

ns ($P > 0.5$) not significant

* ($0.01 < P \leq 0.5$)

** ($0.001 < P \leq 0.01$)

*** ($P \leq 0.001$)

Appendix XXVI. Summary data for sampled stumps

		Number of stumps of each species													Summary statistics						
Site	Area (ha)	SB	YB	RG	IB	GB	AB	WG	NEP	ANG	Ac	cIB	??	Tot.	$S.ha^{-1}$	DUB	HC	AC	~Age	NCS	%CS
1	0.40	0	0	1	0	0	0	0	0	2	0	0	0	3	7.5	50.0	51.7	6.33	20.0	0	0.0
2	0.40	33	0	0	59	7	0	0	0	1	0	0	0	100	250.0	19.6	75.6	6.66	22.5	30	30.0
3	0.18	13	0	0	13	3	0	0	0	0	0	0	0	29	161.1	18.2	79.0	6.31	20.0	10	34.5
4	0.40	0	2	8	0	0	0	0	0	0	0	0	2	12	30.0	17.9	62.9	8.83	69.0	0	0.0
5	0.50	1	0	0	8	0	0	0	0	0	0	0	2	11	22.0	36.5	62.3	7.00	25.0	2	18.2
6	0.40	0	66	2	0	0	0	0	0	0	0	0	0	68	170.0	15.6	93.2	8.21	47.0	0	0.0
7	0.40	1	0	4	0	24	0	0	0	0	0	0	1	30	75.0	20.8	68.7	7.23	28.5	6	20.0
8	0.15	2	0	0	12	0	0	0	0	0	0	0	0	14	93.3	35.5	75.4	6.71	23.0	6	42.9
9	0.16	7	0	0	14	2	0	0	0	0	0	0	1	24	150.0	21.9	81.3	6.88	24.0	8	33.3
10	0.18	3	0	0	9	0	0	0	0	0	0	0	0	12	66.7	37.6	47.9	6.67	22.5	3	25.0
11	0.19	8	0	0	13	1	0	0	0	0	0	0	0	22	115.8	28.4	73.2	7.55	33.0	3	13.6
12	0.40	0	5	3	0	7	0	0	0	0	0	0	0	15	37.5	18.5	99.0	8.60	61.0	1	0.0
13	0.14	3	0	0	4	0	0	0	0	0	0	0	0	7	50.0	15.4	85.0	7.86	38.0	1	14.3
14	0.40	0	1	1	0	0	0	0	0	0	0	35	15	52	130.0	12.8	62.0	7.72	36.0	0	0.0
15	0.40	0	0	3	0	0	0	0	0	0	0	0	0	3	7.5	41.0	86.7	3.33	5.0	0	0.0
16	0.15	4	0	0	3	0	0	0	0	0	0	0	0	7	46.7	26.2	67.9	6.29	19.5	2	28.6
17	0.18	2	0	0	21	0	0	0	0	0	0	0	0	23	127.8	16.2	65.7	5.09	13.0	3	13.0
18	0.14	6	2	0	2	1	0	0	0	0	0	0	0	11	78.6	21.2	52.7	6.46	21.0	1	9.0
19	0.23	16	0	0	7	3	0	0	0	0	0	0	0	26	113.0	36.8	70.0	6.04	18.0	3	11.5
20	0.18	0	4	2	32	7	0	0	0	0	0	0	1	46	255.6	22.8	72.7	6.65	22.5	15	32.6
21	0.40	0	0	1	0	64	0	0	0	0	0	0	1	66	165.0	21.0	78.2	8.62	61.5	1	1.5
22	0.40	0	1	5	0	0	0	0	0	0	0	0	0	6	15.0	29.0	106.7	7.83	30.0	0	0.0
23	0.40	0	0	3	0	0	0	0	0	0	0	0	0	3	7.5	17.0	96.7	8.33	51.5	1	33.3
24	0.40	0	0	1	0	0	0	0	0	0	0	0	1	2	5.0	61.0	75.0	2.50	2.5	0	0.0
25	0.40	0	5	8	0	0	0	0	0	1	0	0	0	14	35.0	27.9	133.6	6.71	23.0	2	14.3
28	0.40	3	0	1	0	0	0	0	0	0	0	0	0	4	10.0	14.3	56.3	7.75	36.5	0	0.0
31	0.40	0	2	17	0	0	0	0	0	0	0	0	0	19	47.5	23.4	96.6	8.16	45.5	0	0.0
32	0.40	3	2	4	0	0	0	0	0	0	0	0	0	9	22.5	32.8	90.0	6.56	21.5	1	11.1
33	0.40	11	0	0	0	0	0	0	0	0	0	0	0	11	27.5	42.5	74.5	7.09	26.5	7	63.6
34	0.40	5	0	2	0	0	1	0	0	0	0	0	0	8	20.0	22.4	57.5	6.38	20.5	2	25.0
35	0.40	13	47	34	0	0	0	0	0	0	0	0	0	94	235.0	18.6	53.8	7.50	32.5	12	12.8

		Number of stumps of each species													Summary statistics						
Site	Area (ha)	SB	YB	RG	IB	GB	AB	WG	NEP	ANG	Ac	cIB	??	Tot.	$S.ha^{-1}$	DUB	HC	AC	~Age	NCS	%CS
36	0.40	0	0	0	0	0	0	0	2	0	0	0	0	2	5.0	69.5	72.5	7.00	25.0	0	0.0
37	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-	-	-	-	-	-
38	0.40	6	15	41	0	0	0	0	2	0	0	0	0	64	160.0	17.6	44.5	6.88	24.0	0	0.0
39	0.40	0	13	26	0	0	0	0	0	0	0	0	0	39	97.5	33.4	60.1	5.62	15.5	0	0.0
40	0.40	0	24	11	0	0	0	0	0	0	0	0	0	35	87.5	32.1	55.0	6.78	23.5	0	0.0
46	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-	-	-	-	-	-
47	0.40	0	0	7	0	0	0	0	1	0	0	0	2	10	25.0	38.1	52.5	6.20	19.0	0	0.0
48	0.40	0	38	2	0	0	0	0	0	0	0	0	0	40	100.0	24.7	31.1	6.78	23.5	0	0.0
49	0.40	0	0	10	0	0	0	0	9	0	0	0	0	19	47.5	27.0	51.3	6.84	24.0	0	0.0
50	0.40	0	0	15	0	0	0	0	2	0	0	0	0	17	42.5	36.9	56.5	8.24	48.0	0	0.0
51	0.40	1	0	0	0	0	2	0	0	0	0	0	0	3	7.5	31.7	80.0	7.00	25.0	0	0.0
52	0.40	0	0	0	0	0	0	0	0	0	0	0	4	4	10.0	44.5	110.0	5.50	15.0	0	0.0
53	0.40	0	0	0	0	0	0	0	1	0	0	0	0	1	2.5	9.0	20.0	6.00	17.5	0	0.0
54	0.40	0	0	0	0	0	0	0	1	0	0	0	0	1	2.5	67.0	100.0	9.00	75.0	0	0.0
55	0.40	0	32	25	0	0	0	0	10	0	0	0	0	67	167.5	15.2	41.3	7.32	30.0	5	7.5
56	0.40	0	0	0	0	0	0	0	3	0	0	0	0	3	7.5	30.7	73.3	5.67	16.0	0	0.0
57	0.40	0	0	0	0	0	0	0	1	0	0	0	8	9	22.5	37.3	83.8	4.44	9.5	0	0.0
58	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-	-	-	-	-	-
59	0.40	0	0	0	0	0	0	0	7	0	0	0	0	7	17.5	16.9	68.6	7.72	35.5	0	0.0
62	0.40	0	0	0	0	0	0	0	3	0	0	0	0	3	7.5	43.7	110.0	3.50	5.5	0	0.0
63	0.40	50	16	4	0	0	0	0	0	0	0	0	0	70	175.0	33.3	55.3	6.81	23.5	2	2.9
64	0.40	10	0	0	0	0	0	0	0	0	0	0	0	10	25.0	22.7	66.5	7.10	26.5	2	20.0
65	0.87	25	3	0	0	0	0	0	0	0	0	0	0	28	32.2	33.1	66.1	7.32	30.0	4	14.3
66	0.40	27	3	1	0	0	0	2	0	0	0	0	0	33	82.5	27.8	76.5	6.21	19.0	4	12.1
67	0.40	51	40	3	0	0	0	0	0	0	2	0	0	96	240.0	25.0	67.9	6.75	23.0	28	29.2
68	0.40	0	0	21	0	0	0	0	0	1	0	0	2	24	60.0	46.8	55.2	7.29	29.5	1	4.2
69	0.40	6	14	6	0	0	0	0	0	0	0	0	1	27	67.5	30.4	44.4	5.37	14.5	4	14.8
70	0.40	0	0	0	0	0	0	0	0	0	0	0	1	1	2.5	20.0	115.0	7.00	28.0	0	0.0
71	0.40	0	0	0	0	0	0	0	0	0	0	0	1	1	2.5	25.0	35.0	8.00	40.0	0	0.0
72	0.40	0	0	11	0	0	0	0	0	0	0	0	0	11	27.5	36.1	67.7	5.91	17.0	0	0.0

		Number of stumps of each species													Summary statistics						
Site	Area (ha)	SB	YB	RG	IB	GB	AB	WG	NEP	ANG	Ac	cIB	??	Tot.	$S.ha^{-1}$	DUB	HC	AC	~Age	NCS	%CS
73	0.40	0	0	0	0	0	0	2	0	0	0	0	0	2	5.0	22.0	55.0	8.00	40.0	0	0.0
74	0.40	5	1	0	0	0	0	0	0	0	0	0	0	6	15.0	37.2	58.3	7.67	35.0	0	0.0
75	0.06	9	0	0	0	0	0	0	0	0	0	0	0	9	150.0	19.0	45.6	5.89	17.0	5	55.6
76	0.40	7	6	3	0	0	0	0	0	0	0	0	0	16	40.0	24.1	71.3	5.25	14.0	4	25.0
77	0.40	5	15	5	0	0	0	0	0	0	0	0	0	25	62.5	24.3	61.8	7.60	34.0	2	8.0
78	0.40	3	8	5	0	0	0	0	0	0	0	0	0	16	40.0	25.7	73.1	5.25	14.0	3	18.8
79	0.29	9	2	2	0	0	0	0	0	0	0	0	0	13	44.8	24.1	58.1	5.69	16.0	0	0.0
80	0.08	5	0	0	0	0	0	0	0	0	0	0	0	5	62.5	13.6	59.0	3.20	4.5	2	40.0
81	0.40	0	0	13	0	0	0	0	2	0	0	0	0	15	37.5	34.7	81.0	4.00	7.5	0	0.0
82	0.40	0	4	9	0	0	0	0	0	1	0	0	0	14	35.0	22.4	49.6	6.57	22.0	0	0.0
83	0.40	60	25	35	0	0	0	0	0	0	2	0	0	122	305.0	18.6	65.9	7.21	28.0	16	13.1
84	0.40	57	1	5	0	0	8	1	0	0	0	0	0	72	180.0	23.7	70.7	7.08	26.0	3	4.2
85	0.50	43	7	6	0	0	1	1	0	0	1	0	1	60	120.0	21.6	60.3	6.03	17.5	9	15.0
86	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-	-	-	-	-	-
87	0.40	3	4	1	0	0	0	0	0	0	0	0	0	8	20.0	18.6	95.0	7.38	30.5	0	0.0
88	0.40	0	12	0	0	0	0	0	2	0	0	0	0	14	35.0	37.0	77.3	7.00	25.0	0	0.0
89	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-	-	-	-	-	-
93	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-	-	-	-	-	-
95	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-	-	-	-	-	-
96	0.40	0	0	0	0	0	0	0	0	0	0	0	6	6	15.0	20.5	43.3	5.83	16.5	0	0.0
97	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-	-	-	-	-	-
98	0.08	5	0	0	0	0	0	0	0	0	0	0	0	5	62.5	46.6	39.0	4.00	7.5	2	40.0
99	0.35	3	0	0	0	0	0	0	0	0	0	0	0	3	8.6	41.0	68.7	7.67	35.0	0	0.0
100	0.06	0	1	0	0	0	0	0	0	0	0	0	0	1	16.7	48.0	55.0	7.00	25.0	0	0.0
101	0.40	0	0	0	0	0	0	0	0	0	0	0	1	1	2.5	30.0	65.0	9.00	75.0	0	0.0
102	0.08	0	2	0	0	0	0	0	0	0	0	0	0	2	25.0	26.0	87.5	8.00	40.0	0	0.0
103	0.40	0	14	0	0	0	0	0	0	0	0	0	0	14	35.0	24.1	77.9	6.93	24.5	2	14.3
104	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	-	-	-	-	-	-
105	0.40	53	15	20	0	0	0	0	0	0	0	0	0	88	220.0	20.3	67.7	7.50	32.5	1	1.1
106	0.40	12	10	0	0	0	0	0	0	0	0	0	0	22	55.0	25.8	52.0	5.55	15.0	0	0.0

		Number of stumps of each species													Summary statistics						
Site	Area (ha)	SB	YB	RG	mIB	GB	AB	WG	NEP	ANG	Ac	cIB	??	Tot.	$S.ha^{-1}$	DUB	HC	AC	~Age	NCS	%CS
107	0.40	0	0	2	0	0	0	0	0	0	0	0	8	10	25.0	20.6	44.5	8.00	40.0	1	10.0
108	0.40	19	7	0	0	0	0	0	0	0	0	0	0	26	65.0	20.7	70.0	7.96	39.5	1	3.9
109	0.40	8	39	4	0	0	0	0	0	0	0	0	0	51	127.5	22.4	37.8	6.92	24.5	0	0.0
110	0.40	1	0	0	0	0	0	0	0	0	0	0	3	4	10.0	21.8	63.8	7.75	36.5	0	0.0
123	0.40	0	0	4	0	0	4	0	0	0	0	0	0	8	20.0	12.3	76.9	2.25	2.0	1	12.5
Tot.	34.40	633	492	397	197	119	16	6	46	6	5	35	62	2014	58.55	23.9	65.2	6.92	24.5	221	11.0

SB = stringybark (various spp.); YB = yellow box *E. melliodora* ; RG = red gum *E. blakelyi* ; IB = red ironbark *E. sideroxylon* ; GB = grey (& white) box *E. moluccana* & *E. albens* ; AB = apple box *E. bridgesiana* ; WG = white (& mountain) gum *E. viminalis* & *E. dalrympleana*; NEP = New England peppermint *E. nova-anglica* ; ANG = *Angophora floribunda*; Ac = *Acacia* spp. ; ?? = 'light' species (species uncertain).

$S.ha^{-1}$ = no.stumps per hectare   DUB = diameter under bark (cm)   HC = height of cut (cm)   AC = age class   NCS = no. coppice stumps   %CS = % coppice stumps

Appendix XXVII. Measurements of DBH, height (HT) and fuelwood volume (VOL) for fuelwood species planted in southern New England.

Spp.	Site	No.	AGE (mnths)	DBH (cm) mean	DBH (cm) max	HT (m) mean	HT (m) max	VOL (m^3) mean	VOL (m^3) max
Ad	P6 i	30	30	no data		4.7 ± 0.2	7.0	no data	
	P12	17	42	4.7 ± 0.5	9.0	3.9 ± 0.2	5.6	0.005 ± 0.001	0.020
	P13 i	13	42	5.5 ± 0.8	9.0	3.8 ± 0.3	5.8	0.007 ± 0.002	0.019
	P13 ii	18	42	6.8 ± 0.6	13.5	4.3 ± 0.2	6.9	0.011 ± 0.003	0.042
	P5 i	103	52	6.1 ± 0.2	15.5	4.4 ± 0.1	8.3	0.009 ± 0.001	0.073
	P17	67	52	6.9 ± 0.3	11.5	4.5 ± 0.1	7.4	0.012 ± 0.001	0.032
	P7 ii	5	62	11.7 ± 1.0	15.0	6.5 ± 0.4	7.5	0.041 ± 0.007	0.068
	P7 iii	12	62	7.3 ± 1.4	16.5	4.0 ± 0.4	6.6	0.017 ± 0.007	0.076
	P4 ii	20	63	5.8 ± 0.5	9.5	5.0 ± 0.3	8.3	0.008 ± 0.001	0.020
	P14i	12	64	12.1 ± 0.8	16.5	5.6 ± 0.3	6.9	0.038 ± 0.005	0.064
	P15	7	64	7.8 ± 0.7	10.0	5.1 ± 0.4	6.5	0.015 ± 0.003	0.028
	P5 ii	74	65	7.4 ± 0.4	15.5	5.3 ± 0.2	8.3	0.016 ± 0.002	0.073
	P6 v	30	67	13.3 ± 0.5	19.0	8.1 ± 0.3	11.0	0.060 ± 0.005	0.153
	P10 i	30	73	15.1 ± 0.7	21.0	8.6 ± 0.4	12.4	0.085 ± 0.008	0.185
	P10 ii	22	73	10.3 ± 0.8	17.5	6.7 ± 0.8	11.7	0.035 ± 0.006	0.105
	P2	260	90	12.4 ± 0.3	21.5	8.1 ± 0.1	12.0	0.055 ± 0.003	0.158
	P16	3	102	13.8 ± 1.6	17.0	7.7 ± 0.2	8.1	0.063 ± 0.017	0.097
	P8	5	162	26.6 ± 3.1	36.0	15.1 ± 1.8	20.9	0.438 ± 0.137	0.947
	P14 ii	3	197	28.3 ± 3.2	31.5	9.1 ± 0.5	10.0	0.293 ± 0.069	0.384
	P3 iii	2	210	32.3 ± 2.8	35.0	9.8 ± 1.2	10.9	0.400 ± 0.094	0.494
Cc	P12	15	42	2.0 ± 0.4	5.0	2.6 ± 0.2	3.9	0.001 ± 0.000	0.004
	P13 i	32	42	1.5 ± 0.2	4.5	2.3 ± 0.1	3.6	0.000 ± 0.000	0.003
	P4 i	33	50	3.3 ± 0.2	5.0	3.2 ± 0.1	4.4	0.001 ± 0.000	0.004
	P18	12	50	2.3 ± 0.4	4.5	2.6 ± 0.2	3.6	0.001 ± 0.000	0.003
	P6 ii	6	51	1.6 ± 0.4	3.0	2.9 ± 0.6	5.2	0.000 ± 0.000	0.001
	P6 iii	2	52	2.0 ± 0.0	2.0	3.0 ± 0.1	3.1	0.000 ± 0.000	0.000
	P17	18	52	2.6 ± 0.4	6.5	2.7 ± 0.2	4.3	0.001 ± 0.000	0.009
	P1 i	8	58	4.9 ± 0.5	7.0	3.7 ± 0.2	4.8	0.005 ± 0.001	0.010
	P4 ii	29	62	2.2 ± 0.3	5.5	2.7 ± 0.2	4.5	0.001 ± 0.000	0.006
	P14 i	20	64	4.0 ± 0.5	9.0	3.5 ± 0.3	6.1	0.004 ± 0.001	0.022
	P16	15	102	17.9 ± 1.2	22.5	7.9 ± 0.2	8.8	0.113 ± 0.012	0.172
	P11	22	197	19.7 ± 1.0	30.0	10.6 ± 0.5	15.7	0.173 ± 0.022	0.381
	P3 iii	21	210	27.5 ± 1.2	39.0	14.7 ± 0.4	18.9	0.427 ± 0.047	0.986
Cl	P13 i	10	42	1.0 ± 0.2	2.0	2.0 ± 0.1	2.6	0.000 ± 0.000	0.000
	P13 ii	9	42	1.4 ± 0.3	3.5	2.2 ± 0.2	3.0	0.000 ± 0.000	0.002
	P5 i	70	52	1.9 ± 0.2	8.0	2.6 ± 0.1	5.3	0.001 ± 0.000	0.015
	P6 iv	5	55	1.1 ± 0.6	3.0	2.2 ± 0.4	3.4	0.000 ± 0.000	0.001
	P7 i	3	56	1.8 ± 0.2	2.0	2.5 ± 0.1	2.6	0.000 ± 0.000	0.000
	P7 ii	6	62	5.7 ± 0.6	7.5	4.5 ± 0.3	5.2	0.007 ± 0.002	0.013
	P7 iii	16	62	2.8 ± 0.5	7.0	2.5 ± 0.2	4.0	0.002 ± 0.001	0.013
	P10 i	13	73	3.1 ± 0.5	6.0	4.3 ± 0.5	7.1	0.002 ± 0.001	0.008
	P10 ii	18	73	5.1 ± 0.6	9.0	4.7 ± 0.4	7.1	0.007 ± 0.001	0.021
Es	P12	9	42	1.1 ± 0.4	2.5	1.8 ± 0.3	2.9	0.000 ± 0.000	0.001
	P13 ii	8	42	0.8 ± 0.3	2.0	1.5 ± 0.2	2.0	0.000 ± 0.000	0.000
	P6 iv	8	55	0.4 ± 0.1	0.5	1.3 ± 0.1	1.7	0.000 ± 0.000	0.000
	P16	2	102	18.0 ± 1.0	19.0	7.7 ± 1.1	8.7	0.109 ± 0.007	0.117
	P3 ii	4	112	5.0 ± 0.6	6.0	3.9 ± 0.4	4.8	0.005 ± 0.001	0.007
	P9	81	300	32.2 ± 1.1	54.0	13.7 ± 0.4	20.8	0.745 ± 0.053	1.990

Spp.	Site	No.	AGE (mnths)	DBH (cm) mean	DBH (cm) max	HT (m) mean	HT (m) max	VOL (m^3) mean	VOL (m^3) max
Ec	P13 ii	13	42	2.6 ± 0.4	4.5	2.5 ± 0.2	3.2	0.002 ± 0.000	0.004
	P6 ii	9	51	3.1 ± 1.1	9.0	2.9 ± 0.6	5.9	0.004 ± 0.002	0.020
	P17	8	52	2.5 ± 0.6	6.0	2.5 ± 0.2	3.2	0.001 ± 0.001	0.006
	P1 ii	13	64	6.2 ± 0.6	11.0	3.6 ± 0.2	5.1	0.008 ± 0.002	0.027
	P10 i	48	73	11.3 ± 0.5	17.0	6.1 ± 0.3	9.5	0.041 ± 0.003	0.090
	P10 ii	31	73	8.5 ± 0.7	15.0	4.5 ± 0.2	7.1	0.021 ± 0.003	0.058
El	P13 i	30	42	4.0 ± 0.3	6.5	2.7 ± 0.1	3.6	0.003 ± 0.000	0.008
	P6 ii	5	51	5.9 ± 1.9	9.5	3.9 ± 0.7	5.3	0.011 ± 0.004	0.019
	P5 i	23	52	3.8 ± 0.4	8.5	3.1 ± 0.2	4.5	0.003 ± 0.001	0.015
	P2	33	90	9.3 ± 0.5	14.0	5.4 ± 0.2	8.9	0.025 ± 0.002	0.071
Em	P6 i	8	30	no data		1.1 ± 0.1	1.6	no data	
	P13 i	7	42	1.0 ± 0.3	2.5	1.8 ± 0.2	2.4	0.000 ± 0.000	0.001
	P13 ii	32	42	1.6 ± 0.2	5.0	1.9 ± 0.1	2.8	0.001 ± 0.000	0.005
	P18	4	50	0.5 ± 0.3	1.0	1.5 ± 0.2	1.8	0.000 ± 0.000	0.000
	P6 v	8	67	2.9 ± 0.9	7.0	2.4 ± 0.4	3.6	0.003 ± 0.001	0.011
	P10 i	20	73	5.0 ± 0.7	13.0	3.2 ± 0.2	5.6	0.007 ± 0.002	0.040
	P10 ii	15	73	2.3 ± 0.7	9.0	1.9 ± 0.3	4.7	0.003 ± 0.001	0.016
	P3 i	3	102	10.5 ± 1.6	13.0	7.9 ± 0.7	8.9	0.037 ± 0.013	0.058
	P16	37	102	15.9 ± 0.6	27.0	6.4 ± 0.2	8.8	0.076 ± 0.008	0.253
Ey	P5 ii	28	65	7.3 ± 0.6	13.0	4.1 ± 0.2	6.2	0.013 ± 0.002	0.045

Ad = Acacia dealbata
Cc = Casuarina cunninghamiana
Cl = C. littoralis
Ec = Eucalyptus caliginosa,
El = E. laevopinea
Em = E. melliodora
Es = E. sideroxylon
Ey = E. youmanii

Appendix XXVIII. Least squares means, standard errors and a summary of AOV statistics for the diameter, height and fuelwood volume of trees of 6 species of varying form and number of stems.

i. plantings aged < 60 months.

		Mean Age	1 stem				2 stems				AOV summary statistics									
			form = 1		form = 2		form = 1		form = 2		adj.	stems			form			stems*form		
Var.	Spp.	(mnths)	N	mean ± se	N	mean ± se	N	mean ± se	N	mean ± se	r^2	*F-ratio*	P	signif.	*F-ratio*	P	signif.	*F-ratio*	P	signif.
D(cm)	*Ad*	47	92	8.9 ± 0.3	91	7.8 ± 0.3	8	9.9 ± 0.8	27	8.4 ± 0.5	0.043	1.756	0.187	*ns*	5.036	0.026	*	0.168	0.683	*ns*
	Cl	50	74	4.3 ± 0.2	13	3.0 ± 0.2	2	3.3 ± 1.3	5	3.3 ± 0.5	0.088	0.234	0.630	*ns*	0.757	0.387	*ns*	0.878	0.351	*ns*
	Cc	48	99	5.5 ± 0.2	16	5.1 ± 0.6	6	4.1 ± 0.7	4	5.3 ± 1.0	0.026	0.809	0.370	*ns*	0.276	0.600	*ns*	1.254	0.265	*ns*
	Ec	47	19	6.6 ± 0.5	1	1.5 ± 0.0	2	7.5 ± 2.5	7	5.1 ± 1.1	0.184	1.838	0.187	*ns*	5.064	0.033	*	0.695	0.412	*ns*
	El	47	35	7.5 ± 0.3	10	6.2 ± 0.7	4	8.3 ± 1.3	6	7.8 ± 0.9	0.077	2.305	0.135	*ns*	1.351	0.250	*ns*	0.275	0.602	*ns*
	Em	41	13	5.6 ± 0.4	15	5.5 ± 0.3	4	6.4 ± 0.4	11	5.2 ± 0.5	0.053	0.318	0.576	*ns*	1.730	0.196	*ns*	1.322	0.257	*ns*
DBH (cm)	*Ad*	47	92	6.8 ± 0.3	91	5.4 ± 0.3	8	7.7 ± 0.7	27	6.1 ± 0.5	0.072	2.117	0.147	*ns*	7.627	0.006	**	0.046	0.831	*ns*
	Cl	50	74	1.9 ± 0.2	13	1.0 ± 0.2	2	1.0 ± 1.0	5	1.0 ± 0.5	0.080	0.547	0.462	*ns*	0.645	0.424	*ns*	0.645	0.424	*ns*
	Cc	48	99	2.7 ± 0.2	16	1.9 ± 0.4	6	1.6 ± 0.4	4	2.0 ± 0.7	0.051	0.819	0.367	*ns*	0.123	0.726	*ns*	1.305	0.256	*ns*
	Ec	47	19	3.4 ± 0.5	1	1.0 ± 0.0	2	2.5 ± 1.5	7	1.2 ± 0.5	0.217	0.072	0.790	*ns*	1.985	0.171	*ns*	0.186	0.670	*ns*
	El	47	35	4.0 ± 0.4	10	3.0 ± 0.5	4	5.4 ± 1.3	6	4.2 ± 0.9	0.074	2.640	0.110	*ns*	2.143	0.149	*ns*	0.012	0.915	*ns*
	Em	41	13	1.6 ± 0.3	15	1.1 ± 0.2	4	3.3 ± 0.6	11	1.0 ± 0.4	0.239	3.941	0.054	*ns*	10.818	0.002	**	4.491	0.041	*
HT (m)	*Ad*	47	92	4.8 ± 0.1	91	3.7 ± 0.1	8	5.0 ± 0.4	27	3.5 ± 0.2	0.219	0.054	0.816	*ns*	30.824	0.000	***	0.853	0.357	*ns*
	Cl	50	74	2.6 ± 0.1	13	2.0 ± 0.1	2	1.6 ± 0.4	5	1.9 ± 0.3	0.142	3.199	0.077	*ns*	0.195	0.660	*ns*	2.218	0.140	*ns*
	Cc	48	99	2.9 ± 0.1	16	2.3 ± 0.6	6	2.3 ± 0.3	4	2.3 ± 0.3	0.093	1.520	0.220	*ns*	1.064	0.304	*ns*	1.257	0.265	*ns*
	Ec	47	19	3.0 ± 0.3	1	1.4 ± 0.0	2	2.5 ± 0.6	7	1.8 ± 0.3	0.239	0.003	0.960	*ns*	2.791	0.107	*ns*	0.409	0.528	*ns*
	El	47	35	3.1 ± 0.1	10	2.7 ± 0.3	4	3.1 ± 0.6	6	2.7 ± 0.3	0.036	0.003	0.956	*ns*	1.449	0.234	*ns*	0.023	0.880	*ns*
	Em	41	13	2.0 ± 0.1	15	1.8 ± 0.9	4	2.3 ± 0.1	11	1.6 ± 0.1	0.198	0.093	0.763	*ns*	9.049	0.005	**	1.920	0.174	*ns*
VOL (m^3)	*Ad*	47	92	0.011 ± 0.001	91	0.006 ± 0.001	8	0.014 ± 0.003	27	0.008 ± 0.001	0.087	1.212	0.272	*ns*	9.623	0.002	**	0.059	0.808	*ns*
	Cl	50	74	0.001 ± 0.000	13	0.000 ± 0.000	2	0.000 ± 0.000	5	0.000 ± 0.000	0.020	0.148	0.701	*ns*	0.148	0.701	*ns*	0.148	0.701	*ns*
	Cc	48	99	0.001 ± 0.000	16	0.001 ± 0.000	6	0.000 ± 0.000	4	0.001 ± 0.001	0.021	0.934	0.336	*ns*	0.004	0.953	*ns*	0.466	0.496	*ns*
	Ec	47	19	0.003 ± 0.001	1	0.000 ± 0.000	2	0.002 ± 0.002	7	0.001 ± 0.000	0.072	0.002	0.964	*ns*	0.649	0.428	*ns*	0.118	0.734	*ns*
	El	47	35	0.004 ± 0.001	10	0.002 ± 0.000	4	0.006 ± 0.004	6	0.004 ± 0.002	0.063	2.065	0.157	*ns*	1.829	0.182	*ns*	0.003	0.954	*ns*
	Em	41	13	0.001 ± 0.000	15	0.000 ± 0.000	4	0.001 ± 0.000	11	0.001 ± 0.000	0.074	2.081	0.157	*ns*	1.970	0.168	*ns*	0.669	0.418	*ns*

Note: signif. = level of signficance (*ns* = not significant ($P > 0.05$); * = significant ($0.01 < P \leq 0.05$); ** = significant ($0.001 < P \leq 0.01$); *** = significant ($P \leq 0.001$))

ii. plantings aged 60 - 89 months.

Var.	Spp.	Mean Age (mnths)	1 stem				2 stems				AOV summary statistics									
			form = 1		form = 2		form = 1		form = 2		adj. r^2	stems			form			stems*form		
			N	mean ± se	N	mean ± se	N	mean ± se	N	mean ± se		*F-ratio*	P	signif.	*F-ratio*	P	signif.	*F-ratio*	P	signif.
D(cm)	*Ad*	67	112	12.2 ± 0.5	71	11.9 ± 0.5	7	17.1 ± 1.1	17	13.8 ± 1.2	0.046	9.512	0.002	**	3.049	0.082	*ns*	1.790	0.182	*ns*
	Cl	68	42	7.1 ± 0.5	4	7.1 ± 2.4	4	8.5 ± 1.6	3	4.3 ± 1.0	0.063	0.230	0.634	*ns*	2.118	0.152	*ns*	2.256	0.140	*ns*
	Cc	63	34	6.8 ± 0.5	8	4.9 ± 0.7	1	8.0 ± 0.0	6	5.2 ± 0.7	0.117	0.268	0.607	*ns*	2.846	0.099	*ns*	0.097	0.756	*ns*
	Ec	72	48	14.5 ± 0.5	16	10.8 ± 1.1	11	16.8 ± 0.9	16	11.1 ± 1.2	0.224	2.029	0.158	*ns*	24.857	0.000	***	1.122	0.292	*ns*
	Em	72	8	9.6 ± 1.0	16	8.1 ± 0.8	1	6.0 ± 0.0	15	6.1 ± 0.8	0.170	2.557	0.119	*ns*	0.160	0.691	*ns*	0.227	0.637	*ns*
	Ey	65	24	10.8 ± 0.7	1	6.5 ± 0.0	3	11.8 ± 2.0	0		*insufficient data*									
DBH (cm)	*Ad*	67	112	9.8 ± 0.4	71	8.8 ± 0.5	7	15.1 ± 1.4	17	11.3 ± 1.0	0.077	15.177	0.000	***	5.594	0.019	*	1.908	0.169	*ns*
	Cl	68	42	4.1 ± 0.4	4	2.5 ± 1.4	4	4.3 ± 1.0	3	1.3 ± 0.7	0.106	0.238	0.628	*ns*	4.648	0.036	*	0.390	0.535	*ns*
	Cc	63	34	3.4 ± 0.4	8	1.7 ± 0.4	1	4.5 ± 0.0	6	1.7 ± 0.6	0.167	0.240	0.626	*ns*	4.380	0.042	*	0.259	0.613	*ns*
	Ec	72	48	10.6 ± 0.5	16	6.8 ± 0.9	11	13.0 ± 0.9	16	7.0 ± 1.0	0.289	2.460	0.120	*ns*	35.071	0.000	***	1.606	0.208	*ns*
	Em	72	8	6.1 ± 1.2	16	4.2 ± 0.8	1	3.0 ± 0.0	15	2.3 ± 0.6	0.208	2.451	0.126	*ns*	0.585	0.449	*ns*	0.121	0.730	*ns*
	Ey	65	24	7.1 ± 0.6	1	1.0 ± 0.0	3	9.2 ± 1.4	0		*insufficient data*									
HT (m)	*Ad*	67	112	6.5 ± 0.2	71	5.6 ± 0.2	7	7.7 ± 0.7	17	6.2 ± 0.6	0.047	3.071	0.081	*ns*	5.174	0.024	*	0.427	0.514	*ns*
	Cl	68	42	4.1 ± 0.2	4	3.6 ± 1.4	4	3.9 ± 0.6	3	2.2 ± 0.5	0.082	1.284	0.263	*ns*	2.303	0.136	*ns*	0.817	0.371	*ns*
	Cc	63	34	3.4 ± 0.2	8	2.1 ± 0.2	1	3.1 ± 0.0	6	2.5 ± 0.5	0.256	0.005	0.943	*ns*	3.313	0.075	*ns*	0.366	0.548	*ns*
	Ec	72	48	5.9 ± 0.2	16	4.0 ± 0.3	11	6.5 ± 0.5	16	3.5 ± 0.3	0.378	0.000	0.988	*ns*	47.612	0.000	***	2.345	0.129	*ns*
	Em	72	8	3.7 ± 0.4	16	2.8 ± 0.3	1	2.9 ± 0.0	15	2.0 ± 0.2	0.299	2.097	0.156	*ns*	2.421	0.128	*ns*	0.000	0.982	*ns*
	Ey	65	24	4.1 ± 0.2	1	1.8 ± 0.0	3	4.4 ± 0.4	0		*insufficient data*									
VOL (m^3)	*Ad*	67	112	0.035 ± 0.004	71	0.027 ± 0.003	7	0.077 ± 0.017	17	0.042 ± 0.007	0.069	11.894	0.001	**	7.263	0.008	**	2.592	0.109	*ns*
	Cl	68	42	0.004 ± 0.001	4	0.003 ± 0.002	4	0.005 ± 0.002	3	0.000 ± 0.000	0.038	0.353	0.555	*ns*	1.316	0.257	*ns*	0.489	0.488	*ns*
	Cc	63	34	0.003 ± 0.001	8	0.001 ± 0.000	1	0.003 ± 0.000	6	0.001 ± 0.000	0.094	0.000	0.994	*ns*	1.339	0.253	*ns*	0.002	0.962	*ns*
	Ec	72	48	0.034 ± 0.003	16	0.014 ± 0.003	11	0.051 ± 0.008	16	0.015 ± 0.004	0.286	3.274	0.074	*ns*	34.840	0.000	***	2.900	0.092	*ns*
	Em	72	8	0.010 ± 0.005	16	0.005 ± 0.001	1	0.001 ± 0.000	15	0.002 ± 0.001	0.171	2.607	0.115	*ns*	0.208	0.651	*ns*	0.533	0.470	*ns*
	Ey	65	24	0.014 ± 0.002	1	0.001 ± 0.000	3	0.019 ± 0.006	0		*insufficient data*									

Note: signif. = level of signficance (*ns* = not significant (P > 0.05); * = significant (0.01 < P ≤ 0.05); ** = significant (0.001 < P ≤ 0.01); *** = significant (P ≤ 0.001))

iii. plantings aged ≥ 90 months.

		Mean	1 stem				2 stems				AOV summary statistics									
		Age	form = 1		form = 2		form = 1		form = 2		adj.	stems			form			stems*form		
Var.	Spp.	(mnths)	N	mean ± se	N	mean ± se	N	mean ± se	N	mean ± se	r^2	*F-ratio*	P	signif.	*F-ratio*	P	signif.	*F-ratio*	P	signif.
D(cm)	*Ad*	91	184	14.7 ± 0.3	40	17.2 ± 0.6	21	18.1 ± 1.5	16	16.7 ± 1.8	0.080	3.218	0.074	*ns*	0.510	0.426	*ns*	6.182	0.014	*
	Cc	177	43	26.5 ± 1.2	9	27.6 ± 1.7	5	30.0 ± 3.8	1	23.5 ± 0.0	0.022	0.004	0.950	*ns*	0.356	0.553	*ns*	0.732	0.396	*ns*
	El	90	29	12.7 ± 0.7	2	16.0 ± 1.5	1	13.0 ± 0.0	1	24.5 ± 0.0	0.030	0.392	0.533	*ns*	0.154	0.695	*ns*	1.156	0.285	*ns*
	Em	102	18	18.0 ± 0.8	3	16.7 ± 2.4	6	19.8 ± 1.2	10	20.9 ± 1.3	0.097	2.072	0.153	*ns*	9.766	0.002	**	0.074	0.786	*ns*
DBH (cm)	*Ad*	91	184	11.8 ± 0.2	40	13.8 ± 0.6	21	14.4 ± 1.2	16	13.5 ± 1.6	0.063	2.627	0.106	*ns*	0.603	0.438	*ns*	4.120	0.043	*
	Cc	177	43	21.8 ± 1.1	9	21.6 ± 1.4	5	25.2 ± 3.0	1	19.5 ± 0.0	0.025	0.029	0.865	*ns*	0.622	0.434	*ns*	0.506	0.480	*ns*
	El	90	29	9.1 ± 0.6	2	10.8 ± 1.8	1	9.5 ± 0.0	1	14.0 ± 0.0	0.039	0.235	0.629	*ns*	1.259	0.265	*ns*	0.351	0.555	*ns*
	Em	102	18	14.3 ± 0.7	3	13.0 ± 2.5	6	17.7 ± 1.4	10	16.1 ± 1.4	0.129	3.541	0.062	*ns*	15.059	0.000	***	0.059	0.808	*ns*
HT (m)	*Ad*	91	184	8.0 ± 0.1	40	8.5 ± 0.2	21	8.5 ± 0.6	16	8.4 ± 0.9	0.014	0.326	0.569	*ns*	0.214	0.644	*ns*	0.864	0.353	*ns*
	Cc	177	43	11.7 ± 0.5	9	10.3 ± 0.8	5	11.3 ± 0.9	1	7.4 ± 0.0	0.048	0.724	0.399	*ns*	1.909	0.173	*ns*	0.454	0.503	*ns*
	El	90	29	5.3 ± 0.2	2	5.4 ± 0.7	1	4.7 ± 0.0	1	6.7 ± 0.0	0.063	0.304	0.583	*ns*	1.214	0.274	*ns*	0.581	0.448	*ns*
	Em	102	18	7.0 ± 0.3	3	5.7 ± 0.9	6	7.2 ± 0.4	10	5.4 ± 0.0	0.196	0.448	0.505	*ns*	24.326	0.000	***	0.026	0.873	*ns*
VOL (m^3)	*Ad*	91	184	0.049 ± 0.002	40	0.070 ± 0.006	21	0.102 ± 0.043	16	0.089 ± 0.023	0.062	8.227	0.004	**	0.092	0.763	*ns*	1.842	0.176	*ns*
	Cc	177	43	0.258 ± 0.033	9	0.203 ± 0.036	5	0.289 ± 0.072	1	0.115 ± 0.000	0.021	0.057	0.812	*ns*	0.953	0.333	*ns*	0.257	0.614	*ns*
	El	90	29	0.023 ± 0.003	2	0.032 ± 0.011	1	0.020 ± 0.000	1	0.067 ± 0.000	0.021	0.072	0.789	*ns*	0.046	0.830	*ns*	0.956	0.331	*ns*
	Em	102	18	0.063 ± 0.007	3	0.049 ± 0.018	6	0.095 ± 0.020	10	0.071 ± 0.013	0.126	5.532	0.020	*	14.247	0.000	***	0.234	0.629	*ns*

Note: signif. = level of signficance (*ns* = not significant ($P > 0.05$); * = significant ($0.01 < P \leq 0.05$); ** = significant ($0.001 < P \leq 0.01$); *** = significant ($P \leq 0.001$))

Appendix XXIX: Fuelwood production and the Greenhouse Effect

1. Definition

Of an average 341 $W.m^{-2}$ of shortwave radiation reaching earth from the sun, 105 $W.m^{-2}$ is reflected directly to space from the effects of albedo, surface reflection and back-scattering by airborne particles, 68 $W.m^{-2}$ is absorbed by water vapour, dust and ozone, and the remaining 168 $W.m^{-2}$ is absorbed at the earth's surface thence re-emitted to space as long-wave (infra-red) terrestrial radiation (Bengtsson 1994). The 'Greenhouse Effect' is a natural phenomenon in which a proportion of this outgoing long-wave radiation is intercepted and absorbed by 'greenhouse gases' (water vapour, CO_2 , CH_4 , N_2O, NO_x, O_3 , chloro-flouro-carbons (CFCs)) to warm the atmosphere. It is fundamental to life on earth; its absence would result in an average global temperature of -18°C compared to the present 15°C (Bengtsson 1994). The recently perceived phenomenon of 'global warming' is not the result of the Greenhouse Effect *per se*; moreso the result of human intervention in global gaseous exchange in which atmospheric concentrations of greenhouse gases, particularly CO_2, are increasing largely as a result of fossil fuel burning and deforestation. This is termed the 'Enhanced Greenhouse Effect (EGE)'.

Various natural phenomena such as El Niño, random changes in atmospheric and oceanic circulation, and volcanic eruptions cause fluctuations in mean global temperature. Despite a 0.5°C increase in global temperature and a 12 mm rise in sea levels since 1900 (Wigley 1993), these factors have been the focus of greenhouse conjecture and conservatism, and may yet result in what Waterstone (1993) described as 'our drifting on a sea of platitudes'. Yet long-term global monitoring of atmospheric CO_2 demonstrates an irrefutable increase in atmospheric concentration from a pre-industrial 280 ppmv to more than 350 ppmv at present (Vitousek 1991; Resource Assessment Commission RAC 1992; Bengtsson 1994), with levels of 450 ppmv predicted by 2020 AD (Barlow and Conroy 1988) and 1340 ppmv predicted by 2100 (Bengtsson 1994) under 'business as usual' scenarios. Atmospheric carbon is increasing by about 3 $GtC.yr^{-1}$, equivalent to 2.5% of the annual forest turnover of 120 $GtC.yr^{-1}$ (Barson and Gifford 1989). Marks *et al.* (1991) placed world carbon emissions at 4.75 $GtC.yr^{-1}$ while Wigley (1993) estimated 6.1 $GtC.yr^{-1}$ from fossil fuel burning and 1.6 $GtC.yr^{-1}$ from land use activities. Vitousek (1991) cited papers suggesting a net release of 1.0 $GtC.yr^{-1}$ from global deforestation. These statistics affirm the danger of complacency in EGE.

2. Perceived effects

Anticipated changes in global temperature could result in large-scale disruptions to species, ecosystems and human lifestyles (Gall *et al.* 1992). A mean surface temperature increase of 2.8°C by 2080 has been forecast to increase the level of oceans by about 16 cm through changes to hydrologic cycles, melted glaciers and thermal expansion sea water (Bengtsson 1994). This forecast hinges on the assumption of partial compensation by snow accumulation on Antarctica and Greenland (Bengtsson 1994), and contravenes advocates of polar meltdown. Emanuel *et al.* (1985; cited in Duinker 1990) anticipated a 1.65 million km^2 loss in polar and other ice landscapes and Eckersley (1989) cited literature which predicted sea level rises of up to 1.4 m by 2030. It is generally agreed that increased sea levels will force changes on aquatic and littoral ecosystems, may inundate delta valleys and shallow islands and displace human inhabitants, and will perpetuate the potential for storms and cyclones and increase the impact of floods, particularly in tropical and monsoonal climates and receiving catchments.

Changes in the distribution and extent of global vegetation types were modelled and reviewed by Duinker (1990) and Bengtsson (1994). Most notable were the global diminution of sub-tropical, warm temperate and boreal forest and the global expansion of tropical forest, grassland and desert (Duinker 1990). Assuming a doubling in atmospheric CO_2 concentration by 2040, Australia *per se* will experience increased temperatures (1-2°C in northern coastal to 1-4°C inland) and changes in the quantity and distribution of rainfall (10-20% increase in summer rainfall areas; 10-20% decrease in winter rainfall areas) (RAC 1992). According to global biome modelling by Bengtsson (1994), savanna and xerophytic woodland and shrubland will encroach the inland deserts. Although predicted climate change will favour productivity of plantations (Barlow and Conroy 1988; Gifford 1988) and certain forest ecosystems (e.g. tropical forests), there are possible drawbacks with respect to vegetation on the Northern Tablelands of NSW. Solomon (1986, cited in Duinker 1990) examined long-term forest succession in North America by simulating increased rainfall and temperature. A distinctive dieback of extant trees was predicted at most sites. Porter *et al.* (1991) outlined the likely impacts of escalating temperatures on insect pests in agricultural systems; these included changes in geographical distribution and population growth rates, increases in number of generations and extension of the active season, and risk of invasion by migrant pests. Landsberg and Stafford-Smith (1990) demonstrated an increased risk of eucalypt defoliation by insects associated with the interaction between higher temperatures and plant nitrogen levels, implicating increased eucalypt dieback with EGE.

3. Fuelwood combustion and the Enhanced Greenhouse Effect

Global, national and regional contributions

Wood combustion is a complex process in which organic constituents are broken down into the principal products CO_2 and H_2O (section 2.2.5 and Appendix XXX). CO_2 is the major gas implicated in the EGE (Bouwman 1990) and the major gas released from wood burning. Assuming a mean wood density of 0.6 $t.m^{-3}$, the estimated 1989 global fuelwood consumption of 1.80 x 10^9 m^3 (section 1.1.1) represents 1.08 x 10^9 t or 1.08 Gt, just over 10% of the estimated 10 $Gt.yr^{-1}$ global combustion of fossil fuels (Bengtsson 1994). Assuming combustion of 1.0 tC produces about 3.7 tCO_2 (RAC 1992) and that 50% of plant biomass constitutes carbon by weight (Barson and Gifford 1989; Todd 1990; RAC 1992), then total CO_2 emitted from global woodburning in 1989 is crudely estimated at 2.0 Gt (cf. 2.3 Gt; Todd 1990). This is about 9% of the global CO_2 output from fossil fuel combustion (22.6 $Gt.yr^{-1}$) estimated by Wigley (1993) (cf. 10%; Rotty 1986).

Land clearing in Australia since European settlement has resulted in the loss of about 14 Gt of standing biomass and thus 7 GtC, contributing 3-5% of the world's accumulation of atmospheric CO_2 (Scanlan *et al.* 1991). Australia also contributes an estimated 1.2% of global carbon released from the burning of fossil fuels (70 $MtC.yr^{-1}$ or 262 $MtCO_2.yr^{-1}$), representing one of the highest per capita rates in the world at 3.9 $tC.capita^{-1}.yr^{-1}$ or 15 $tCO_2.capita^{-1}.yr^{-1}$ (Barson and Gifford 1989; Marks *et al.* 1991). From residential wood burning in Australia (4.4 $Mt.yr^{-1}$; Forestry Technical Services and University of Tasmania FTS and UT 1989), an estimated gross 8.1 $MtCO_2$ is expelled into Australian skies each year, equivalent to 3% of that released from the burning of fossil fuels (Todd 1990).

Given an urban fuelwood consumption of 17 940 t (section 2.4.1), it follows that about 33 150 tCO_2 or 1.44 $tCO_2.capita^{-1}$ is expelled from Armidale's flues and chimneys each year. Private collectors use an estimated 77 100 L petrol in cutting and transporting 7000 t each year (~ 11 $L.t^{-1}$; section 2.5.4). If a similar rate for all modes of delivery is assumed, then an estimated 188 300 L of petrol is consumed annually. Since petrol emits about 73 $kTCO_2.PJ^{-1}$ (Marks *et al.* 1991) and the energy content of petrol is 3.49 x 10^7 $J.L^{-1}$ (Hinkel 1989), it follows that 2.55 $kgCO_2.L^{-1}$ is released. Thus, about 480 tCO_2 is emitted from fossil fuel burning to cut and deliver Armidale's annual fuelwood supply, 1.5% of the total 31 600 $tCO_2.yr^{-1}$ from wood combustion itself. Based on the Australian average of 15 $t.capit^{-1}.yr^{-1}$ cited above, a total estimate for Armidale's annual CO_2 emission is 345 000 $tCO_2.yr^{-1}$ (population = 23 000). Thus fuelwood combustion contributes about 9% of Armidale's CO_2 emissions, equal to the mean global rate, yet three times the mean Australian rate.

Local impact

Much of the carbon absorbed by trees is oxidised in the short-term via respiration and decomposition, while some is stored for longer periods within wood and soil organic matter (Attiwill 1994). When the forest is harvested for fuelwood and allowed to regenerate, carbon is lost to the atmosphere by accelerated decomposition of soil organic matter and small branches and leaves left *in situ* (Attiwill 1994). Unlike timber products such as furniture, building material, or even fenceposts, in which carbon is retained within the wood fibres for up to 100 years, carbon is released immediately from fuelwood combustion.

There are two schools of thought regarding the impact of fuelwood on the EGE. Where fuelwood is a by-product of land clearing for pastoralism or forestry, net contribution by the combustion of wood is argued by Todd (1990) to be near zero. Fuelwood combustion accelerates the accumulation of atmospheric CO_2 in the short-term but not in the long-term since the wood ultimately decays *in situ* to release CO_2 via respiration. This viewpoint implicates land clearing, and not fuelwood burning, as the agent for long-term carbon flux to the atmosphere. As an adjunct, Todd (1990) implicated chainsaw operation and wood haulage as the main contributors to greenhouse emissions in the wood industry in Australia and concluded "if fossil fuels were used to substitute for all firewood use, it would increase national emissions by about 2 percent". The alternative contention regards deforestation and fuelwood consumption as being synonymous, where continued clearing in the absence of reforestation results in a positive flux of CO_2 from firewood combustion (Marks *et al.* 1991). That is, wood burning is directly responsible for long-term accumulation of CO_2 as a result of the net decline in stored carbon within the forest system. Morse (1985) alluded to the 'mining' of fuelwood in the Canberra region as one might mine coal or oil. This perception is could elicit responsibility (and avoid apathy) within wood-burning communities such as Armidale, and should be promoted as a catalyst for replacement of dead timber on New England farms (see also sections 2.5.1 and 8.2.5).

4. Biological control of EGE

General

Emission control to reduce net CO_2 accumulation may be active or offset. Active measures aim to reduce emission rates, and include carbon taxes, transferable carbon emissions permits and legislation (Marks 1991), as well as increased efficiency in fossil fuel combustion in the transport sector, household energy economising, and greater use of renewable energies (Hoen and Solberg 1994). Offset measures aim to counter emission rates. Reforestation is a well recognised offset measure.

Forests play a major role in maintaining the global equilibrium of CO_2 by fixing it into woody biomass through photosynthesis (Gifford 1988) and releasing it into the atmosphere through biomass decay and decomposition (Hoen and Solberg 1994). An equivalent 10% of the entire load of atmospheric CO_2 encompassing the earth is cycled through forest ecosystems every year (Waring and Schlesinger 1985). Expanding the world's forests would thus increase the capacity for terrestrial carbon sink and mitigate the buildup of atmospheric CO_2 (Sedjo 1989; Schroeder and Ladd 1991; Vitousek 1991; Schroeder 1992). It would also afford flexibility in an era where the probability and impact of global warming are burdened with uncertainty (Hoen and Solberg 1994).

Because pastoral lands neither sequester CO_2 (Turner 1990) nor contain significant above-ground carbon pools (Schroeder 1994), farm forestry presents a transient opportunity to lay down new organic matter faster than it is re-oxidised (Barson and Gifford 1989; Schroeder 1994; Dixon 1995). Young forest assimilates carbon at a much higher rate than mature forest, the rate being mainly a function of its primary productivity (Barson and Gifford 1989). In mature forests, sequestration is more or less equal to dissipation (Eckersley 1989; Bouwman 1990; Turner 1990). Sedjo (1989) estimated that 465 Mha of plantations with an MAI of 15 $m^3.ha^{-1}.yr^{-1}$, representing about 10% of the earth's current forest estate, could sequester the 2900 MtC released annually from deforestation and fossil fuel combustion.

The role of fuelwood plantations in sequestering CO_2.

While woodburning in Australia contributes an estimated 8.1 $Mt.yr^{-1}$ to EGE (part 3) and is 'greenhouse unfriendly', appropriately managed biomass can supply a source of sustainable wood energy with many of the benefits of higher profile renewable energy sources such as solar and wind (Todd 1990). In fact the net amount of CO_2 released from wood burning can be significantly reduced if plantations are grown to substitute fossil fuels (Eckersley 1989; Vitousek 1991; Hall and House 1995). This was demonstrated by Vitousek (1991), who predicted the net effects of two plantation options on global concentrations of CO_2 over the next 100 years, assuming a planting rate of 200 Mha (10 $Mha.yr^{-1}$ over 20 years) and a carbon fixation rate of 5 $tC.ha^{-1}.yr^{-1}$. Compared with a predicted 230 Gt by 2070 under a scenario of 'leave and let be', atmospheric accumulation of CO_2 was predicted to be 215 Gt using sequestering plantations and about 195 Gt using biomass plantations. It showed that reforestation could become a logically consistent long-term approach to counteract EGE (Vitousek 1991), although reforestation alone was clearly insufficient to halt or reverse EGE.

5. A plantation strategy for Armidale to counter local contributions to EGE

Preamble

The following scenario differs in two ways from the current school of thought about Greenhouse amelioration using vegetation. First, answers to carbon reduction are often sought from a global viewpoint (e.g. Sedjo 1989; Schroeder 1991). This analysis describes steps which can be taken to ameliorate regional emissions in line with global expectations. Second, many contemporary scenarios intend that plantations be grown for at least 50 years to 'buy time' while other avenues are explored to counter the EGE (Dyson 1977; Schroeder and Ladd 1991; Schroeder 1992). This analysis seeks to curtail CO_2 emissions within the time-frame for growth and management of short-rotation coppice plantations and shelterbelts (Chapter 9).

Plantation quantification

The major aim for a responsible fuelwood industry and wood using community is to offset the volume of CO_2 emitted from wood combustion with fuelwood plantations. The question is thus posed - how much land is required to sequester 32 100 tCO_2 every year? To answer this, it is necessary to understand the growth increments of local stands, the proportion of carbon within biomass, and the relative contribution of stemwood, branches, leaves and roots to total biomass (Vitousek 1991).

For the purpose of the following carbon budget, an average biomass growth increment of 12 $t.ha^{-1}.yr^{-1}$ (stem, branches, foliage, roots) is adopted for a 15 year rotation on the Northern Tablelands. Since 50% of plant biomass by weight constitutes carbon (Barson and Gifford 1989; Todd 1990; RAC 1992), then total carbon assimilated over 15 years is 6 $tC.ha^{-1}.yr^{-1}$, equivalent to 22 $tCO_2.ha^{-1}.yr^{-1}$. This compares with the mean rate of 8-10 $tC.ha^{-1}.yr^{-1}$ in *Eucalyptus regnans* forest in Victoria (Attiwill 1994) and an average 6.4 $tC.ha^{-1}.yr^{-1}$ in New Zealand's *Pinus radiata* plantations over a one year period in 1988 and 1989 (Hollinger *et al.* 1993). Schroeder (1994) reviewed four studies to estimate a median carbon storage of 63 $tC.ha^{-1}$ in the above-ground woody biomass of temperate agroforests cut on a 30 year rotation. Carbon fixation rate was 3.9 $tC.ha^{-1}.yr^{-1}$.

Assuming that 481 500 tCO_2 is released from firewood consumption in Armidale in the next 15 years, a total area of about 1460 ha of fuelwood plantations would be required to offset all CO_2 emitted from residential woodburning. Considering that 38 300 people inhabit the study region (cf. 23 000 in Armidale, section 2.2.4), this can be amended to 2430 ha. Since firewood combustion represents 9% of CO_2 output by Armidale residents, and assuming the same for New England farmers, a total plantation estate of 2430 ha would contribute 45% towards the multi-national expectation of a 20% reduction in CO_2 emissions associated with human activity by 2005 (Marks 1991; Marks *et al.* 1991). It follows that 5400 ha of farm plantation in the study region, less than 1% of the estimated 700 000 ha of cleared private land (scattered and isolated trees, Chapter 5), could meet the 20%-reduction objective. This emphasises the potential to meet global requirements for greenhouse reduction on a regional scale whilst enjoying various other benefits of trees on farms (Chapter 9).

6. Summary

The present lack of replacement of dead standing trees in the Armidale region renders urban and rural wood burning a net source of CO_2 to the atmosphere, and a contributor to EGE. The role of tree plantations to provide fuelwood and reverse regional CO_2 emissions has been explored. It appears that establishing plantations in the New England landscape offers not only the opportunity to counteract emissions from woodburning *per se*, but could be undertaken on a scale to meet global expectations regionally. An area of 5400 ha of fuelwood plantation would sequester about 1.78 $MtCO_2$ in the next 15 years, more than offsetting the 0.79 $MtCO_2$ which is likely to be emitted from wood-burning should energy use in the region remain the same.

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Appendix XXX : Woodsmoke

1. Introduction

Research and development in woodheater design in the last two decades has resulted in the production of 60 to 70% efficient systems, making woodheating economically attractive as well as aesthetically appealing. The resultant increase in sales and operation has exposed a problem not evident in the early days of open fireplaces - outdoor woodsmoke pollution. Modern air-tight woodheaters utilise 'cool burn' conditions to maximise efficiency, in which poor internal air turbulence and insufficient oxygen result in prolonged and incomplete combustion. More woodsmoke is consequently emitted into the atmosphere from modern woodheaters than from traditional open fires (Quraishi *et al.* 1984; Core *et al.* 1984) or even old stoves which allow secondary air to leak through cracks (Roper 1983).

The chemical and physical processes involved in the burning of wood are intriguingly complex. Of the combustion of any material containing hydrogen and carbon, Cooper (1980) stated "a myriad of initial pyrolysis products formed during partial combustion are mixed in a sea of chemical reactivity including pyrolysis, oxidation and reduction". Pyrolysis is the thermal degradation of cellulose, the major component of wood, and is the principal source of combustible volatile gases that fuel the flaming process (Shafizadeh 1984). Pyrolysis produces tar, charcoals and volatiles which, at high temperatures with ample oxygen, combust to form the end products CO_2 and H_2O. Under the oxygen deficient conditions of night-time woodstove operation, however, incomplete combustion produces from initial pyrolysis products the ambient pollutants of concern, including reactive hydrocarbons or volatile organic compounds (VOCs), polycyclic organic matter (POMs), oxides of nitrogen (NO_x), oxides of sulphur (SO_x), and carbon monoxide (CO) (Quraishi *et al.* 1984; Quraishi 1985a). POMs are formed during the combustion of any compounds containing hydrogen and carbon, such as the cellulose, hemicellulose and lignin found in wood. They comprise a complex group of organic compounds containing multiple fused organic rings and are classified into three classes of organic carcinogens, of which the polycyclic aromatic hydrocarbons (PAHs) are most prominent and generally synonymous for POMs (Quraishi 1985a).

A mass emission method is used below to estimate the relative contribution of residential wood combustion (RWC), motor vehicles and coal-boiler combustion to emissions of particulate matter and carbon monoxide into Armidale air-shed during a winter's night. The results are discussed in relation to 1995 particulate measurements undertaken by the Environment Protection Authority (EPA) using an integrated nephelometer and high volume sampler. Health implications are reviewed and methods for pollution control are assessed.

2. Woodsmoke composition

Particulate matter

Particulate matter is dispersed matter existing in the condensed solid or liquid phase in the atmosphere. The size of individual particles ranges from 0.005 µm to 500 µm (Fennelly 1975; cited in Quraishi 1985a). There are numerous biological, geological and anthropologic sources. Biological and geological particles arise naturally, the former including suspended spores, insect parts and vegetative fragments (Cooper *et al.* 1981), the latter comprising dust from wind erosion, volcanic activity, earthquakes and meteorites. Anthropologic particles result mostly from combustion sources including slash-burn operations, coal-fired power stations, heavy industry, motor vehicle emissions, and RWC. Woodsmoke particles comprise of a variety of aliphatic, olefinic and polynuclear aromatic hydrocarbons (Cooper 1980). Hall and DeAngelis (1981) identified 75 organic species in woodsmoke, including 22 POMs and various aldehydes, furans, phenols and naphthalenes. Cooper (1980) referred to a study in which 14 carcinogens were characterised, representing 0.5% of total particles emitted from woodheaters and fireplaces. These escape from the firebox during combustion and are either deposited as creosote on the inside flue wall (Pilcher and Ghajar 1985) or released into the residential airshed as particles.

Carbon monoxide (CO)

Woodheaters have been found to emit substantial quantities of CO. Cooper (1980) estimated that an average motor vehicle would have to travel 830 km on a highway to emit as much CO as a woodstove operating on a normal winter's day, and Keough (1986) cited a United States Environment Protection Authority (USEPA) report stating that woodstoves generate more CO in the US than all industry. Similar to particulates, outdoor CO emissions from woodstoves are significantly higher than those from open fireplaces (Lamason 1982 cited in Stevens 1985) and indoor emissions are higher for fireplaces and non-airtight stoves (Traynor *et al.* 1987). There appears to be little correlation between the levels of particles and CO emitted from different wood-burning appliances (Todd 1990). CO combines readily with haemoglobin in the blood to form carboxy-haemoglobin (CO has 210 times the affinity of O_2 for haemoglobin). This prevents O_2 transfer and can lead to headaches, dizziness and mental confusion, and impairment of vision and hearing (Quraishi *et al.* 1984).

3. Health impacts of woodsmoke particles

Outdoor pollution

The adult human lung has a surface area of between 120 and 150 m^2 in which O_2 and CO_2 are exchanged between the external atmosphere and the blood. An estimated 9000 to 12 000 L of air are exchanged each day for a person at rest or gently exercising (Streeton 1990). Through a variety of defence mechanisms including the cough reflex and mucociliary clearance (Streeton 1990), the human pulmonary system is capable of avoiding the health threat of ambient particles in most circumstances. Sub-micron particles pass continuously into the human lung via a complex network of air passages (bronchioles) and are deposited within a lining of mucus at the branching points (bifurication zones) before reaching the alveoli. The particles are cleared by cilia and the lung passages remain unobstructed under normal conditions, however, in situations where particles occur in high concentrations, the ciliary mechanism is over-committed and particles accumulate. This is evident in cigarette smokers, where carcinogenic fragments build up over time to form malignancies or cancers.

Human exposure to emissions from RWC is arguably greater than from any other stationary source because particles are discharged into residential areas close to ground level during poor atmospheric dispersion. Fine particulates (< 2.5 µm aerodynamic diameter) are the most significant of the potentially harmful substances in woodsmoke (Fels *et al.* 1990); the majority of woodsmoke particles (~80%) occur in the submicron (0.1-1.0 µm) fraction and are thus respirable (Core *et al.* 1984). Benzo(*a*)pyrene (B*a*P) is the most toxic woodsmoke carcinogen (Lynn 1976) and has received the most publicity. Like all organic particles, it is a product of incomplete combustion from various sources including coal-fired power stations, bushfires, industrial incinerators, motor vehicles, cigarettes and RWC. While no official woodheater study has been conducted in Australia to determine their effects on human health (Quraishi and Todd 1986), Taylor and Jakeman (1993) cite papers stating that woodfires contribute significantly to particulate levels in the ACT, reducing both human health and visibility. B*a*P has been associated with cancer in London chimney sweeps (Freeman and Cattell 1990), and together with other woodsmoke particles, is implicated in the cause of between 600 and 800 cancer cases per year from exposure to woodsmoke in the US (Keough 1986). Quraishi (1985a) referred to a publication which estimated that woodsmoke caused five additional lung cancer deaths per year per 100 000 people exposed to woodsmoke emissions in the US.

More recent studies suggest that health problems associated with exposure to fine particles could be much more serious. Dockery *et al.* (1993) monitored human mortality over 12-14 years from a sample of 8111 people living in 6 US cities. After adjusting for smoking and other risk factors, statistically significant and robust relationships were observed between mortality rate (from lung cancer and cardiopulmonary disease) and long-term fine particle concentration. Human mortality associated with fine particulate matter in a city with a long-term average concentration of 29.6 $\mu g.m^{-3}$ was 1.26 times greater than that in a city with an average 11.0 μg.m^{-3} (Dockery *et al.* 1993). The relationship was near linear, suggesting a 1.4% increase in particle-related mortality per 1.0 μg.m^{-3} increase in long-term concentration. In a similar yet more exhaustive 9-year study in which human mortality was measured in relation to exposure factors using 295 223 people living in 50 US cities, adjusted mortality rate was 1.17 times greater in cities with a mean fine particulate level of 33.5 μg.m^{-3} than in cities with a mean level of 9.0 μg.m^{-3} (Pope *et al.* 1995). This suggested a 0.7% increase in particle-related mortality per 1.0 μg.m^{-3} increase in the long-term fine fraction. Both studies concluded that combustion-source air-pollutants may be important contributors to development of cardiopulmonary illness and subsequent mortality. USEPA claimed that a 10 μg.m^{-3} increase in urban PM_{10} (particulate matter ≤ 10 μm diameter) concentration results in a 1% increase in overall death rate, implicating that 60 000 people in the US and 10 000 in the UK die each year from exposure to PM_{10} (Bown 1994).

Short term exposure to extreme particulate concentrations can initiate or complicate chronic respiratory diseases including asthma, pneumonia, bronchitis, emphysema and cancer (Cooper 1980). Schwartz *et al.* (1993) compiled daily records of asthma emergency room visits in 1990 and 1991 from 8 hospitals in the Seattle area to determine whether exposure to PM_{10} enhanced the risk of asthma. Mean and maximum 24-hr PM_{10} concentrations over the 395 day study period were 29.6 and 103.3 μg.m^{-3}, respectively. After controlling for weather, season, time trends, age, hospital, and day of the week, daily counts for persons under age 65 were significantly associated with PM_{10} exposure the previous day, although exposure to the mean PM_{10} concentration over the previous 4 days was a better predictor. The relationship was near-linear, with PM_{10} exposure responsible for a 12% increase in asthma emergency visits at a mean concentration of 30 μg.m^{-3}, and a 30% increase in visits at a mean concentration of about 60 μg.m^{-3} (Schwartz *et al.* 1993). In a concurrent study undertaken in Seattle, Keonig *et al.* (1993) observed fine particle matter from wood burning to be significantly associated with acute respiratory irritation in young asthmatic children.

Indoor pollution

The relationship between outdoor and indoor air quality is unclear. Highsmith *et al.* (1988) found indoor particle mass to be lower than outdoor particle mass during wood burning episodes while Daisey *et al.* (1989) and Kaarakka *et al.* (1989) found no significant difference between indoor and outdoor levels during burn and non-burn periods. The least understood source of indoor woodsmoke emissions is that from outdoors. With a typical air exchange rates (AER) of two hours (Highsmith *et al.* 1988), outdoor woodsmoke concentrations contribute as much or more to indoor levels than airtight wood heaters (Kaarakka *et al.* 1989). Approximately 30% of Armidale households (6600 people) used energy sources other than firewood in 1990 - in many respects these people are the passive smokers of RWC.

Indoor pollution is commonly related to stove operation, occurring in pulses when a damper is closed during refuelling (Traynor *et al.* 1987; Highsmith *et al.* 1988) or a door left open after refuelling

(Daisey *et al.* 1989). In some cases a defective stove or a blocked flue will cause unacceptable short term levels of contamination (Quraishi and Todd 1987; Kaarakka *et al.* 1989). Sexton *et al.* (1984b) cited several studies which have found that indoor concentrations of organic particles can increase during woodstove operation, especially when appliances are poorly installed, maintained or operated. Traynor *et al.* (1987) reported a 'worst case' example of operation of a non-airtight stove. Average indoor B*a*P source strength was 57 $\mu g.h^{-1}$ compared to a normal of about 0.05 $\mu g.h^{-1}$ for air-tight stoves. In general, residents are more at risk from indoor pollution when open fireplaces are used because smoke can frequently enter the living space when the room pressure drops due to air movement outside (Quraishi and Todd 1987).

A less documented form of indoor pollution results from human exposure to contaminants produced from combustion of inappropriate materials. Quraishi (1987) cited a report which stressed the serious health hazard of burning treated timber containing chromate, copper and arsenic (CCA). Eight members of a rural family showed various ailments symptomatic of prolonged exposure to high concentrations of CCA residue in the ash and dust of their homes after repeatedly burning treated timbers. These included conjunctivitis, bronchitis, pneumonia, sensory hyperaesthesia of limbs (extremely sensitive skin), dermatitis, severe alopecia (hair loss), gastrointestinal disturbances, blackouts and seizures, nosebleeds, ear infections and muscle cramps.

Housefire

Another major organic product of wood combustion is creosote, which consists of condensable organic compounds of high molecular weight which accumulate and stick to the inside of the chimney before escaping into the atmosphere. Three forms are identified by Quraishi (1985a): a watery, sappy fluid; a thin tacky deposit; and a dry, brittle crust most familiar to wood burners. Similar to woodheater emissions in general, where pH values for woodstove flue gas condensate solutions are 2.8-4.2 (Burnet *et al.* 1986), creosote is acidic and therefore corrosive to many materials (Quraishi 1985a). It can impede smoke passage up the flue and is a common cause of inefficient burning and indoor smoke spillage or leakage. A health hazard from creosote is potential chimney fire. Pilcher and Ghajar (1985) refer to an anonymous study which stated that 22 000 housefires and 800 deaths occurred in the US in 1981 as a result of fires caused by woodstoves. As shown by Todd *et al.* (1985), however, not all housefires associated with woodheaters result from creosote. Housefire accident reports in Tasmania from early 1980 to mid 1983 revealed a total 59 fires associated with woodheaters, of which 47% were attributed to poor installation of either the flue or heater, 24% were caused by poor maintenance and 10% were caused by negligent operation. The remaining 19% were unknown, although birds nests in the flue accounted for two fires (Todd *et al.* 1985).

4. Monitoring woodsmoke

Source versus receptor models

The majority of research associated with woodsmoke involves the sampling of polluted air at either the source or receptor level. The source approach involves low volume, short duration sampling directly from the flue or chimney stack using filters. Particles adhered to filters collected from source and receptor sampling are subsequently analysed using chemical procedures such as x-ray fluorescence elemental analysis, gas chromatography and mass spectrometry. Source sampling is useful in comparing different burning regimes and timber species (Piispanen *et al.* 1984; Quraishi 1987). It produces relative emission data, usually expressed in grams emitted per kilogram of fuelwood consumed ($g.kg^{-1}$), and results in the development of woodstove emission factors (e.g. Butcher and Ellenbecker 1982; Quraishi *et al.* 1984).

The receptor approach involves the use of high-volume samplers (Pilgrim *et al.* 1984) in which ambient air is sucked through a filter or series of filters at some distance from the source for a 12 or 24 hour period. The filters are either Teflon coated and/or quartz fibre (Stevens 1985; Rau 1989), designed to capture airborne particulate matter. Receptor sampling allows air pollution concentrations ($\mu g.m^{-3}$) to be determined for individual chemicals, and is useful for providing policy directives for emission control in terms of health goals. Analysis is often complicated by the need to apportion each chemical between its respective sources (e.g. motor vehicle exhaust, fugative dust, woodsmoke), requiring radio-tracing (Cooper *et al.* 1981; Ramdahl *et al.* 1984) or chemical mass balance (Khalil *et al.* 1983). Another form of receptor sampling involves integrated nephelometers, which measure the degree to which light is scattered by ambient particles (Heggie and Hawke 1984). It is recommended as the most useful of currently available instruments for measuring atmospheric fine particles in Australia (Heggie and Hawke 1984).

The mass emission approach

A far less costly method for determining woodsmoke concentration is based on the mass emission method, in which the total mass of wood burnt (kg) is multiplied by the average emission rate ($g.kg^{-1}$) (Dasch 1982; Myers 1985; Dasch and Cadle 1989). Mass emission analysis enables construction of an emission inventory; a list of the amount of pollutants from all sources entering the air over a given period of time. Using consumption data obtained in Chapter 2, the mass emission approach can be used to estimate the quantity of particles and CO emitted into the Armidale airshed on 'normal' and 'extreme' winter evenings from RWC, motor vehicles and the UNE college boiler station.

Other sources of emission are deemed negligible in the context of Armidale's airshed. On a per unit heat output, heating with wood generates 20 times more particulates than oil and 50 times more than gas (Rau 1989). Pollution from oil and gas are thus considered negligible, considering that only 15% of Armidale residents use oil for interior heating and 12% use gas (Figure 2.5). Course carbon particles of a biogenic nature including starch, spores, pollen, fungal hyphae, insect parts, leaf and paper fragments and wood fibres (Cooper *et al.* 1981) occur in the atmosphere, but are assumed negligible in winter. Airborne particles are present in the form of aerosols driven from distant sources (Sexton *et al.* 1985) including volcanic activity and the large scale burning of forest fuels as occurs in the Amazon. These are ever-present in the atmosphere and are accounted for as background concentrations. Fugative dust and reintrained road dust (Sexton *et al.* 1984a; Zib 1984) are other sources of airborne particulates. Fugative dust in the US is estimated to account for 90% of national particulate emissions (Zib 1984), with 50% generated by wind erosion and a large proportion of the remainder due to travel on unpaved roads. On a national scale, the contribution of dust to total particles in Australia must also be considered highly significant, yet from a night-time Armidale perspective, dust is unlikely to contribute to urban haze at all.

5. Emission factors and emission rates

Residential wood combustion

An emission factor is an expression of the grams of a pollutant released per kilogram of fuel combusted and an emission rate expresses the grams of pollutant emitted during a one hour period (Todd 1993). Emission factors and rates are obtained using various sampling techniques which involve the capture of emissions from the point of discharge (usually the flue) and chemical analysis of captured particles. Emission testing experiments have revealed extreme variation in results from burning tests due to small, uncontrollable differences between fires (Quraishi and Todd 1986; McCrillis *et al.* 1992) and other factors such as stove model, wood characteristics, charging rate and oxygen intake. Todd and Quraishi (1986a) and Quraishi (1985a,b, 1986, 1987) discussed the various extractive and total capture methods to measure particulate emissions, including the Oregon (OM-7), the American Society for Testing Materials (ASTM) Draft, British, Canadian and New Zealand Standard methods and the Condar Emissions Testing System. They conclude that the ASTM draft system, which dilutes the emission stream prior to sampling, best simulates the real world situation.

Wide ranging emission results have been obtained from a variety of methods. Hall and DeAngelis (1981) used EPA Method 5 sampling train to quantify woodsmoke emissions from closed heaters and open fires charged with hardwood. The average particulate emission from closed heaters was 3.0 $g.kg^{-1}$ and average emission from open fires was 2.3 $g.kg^{-1}$. The average CO emission rate was 110 $g.kg^{-1}$ from woodstoves and 30 $g.kg^{-1}$ from fireplaces. Dasch (1982) used the same technique to evaluate hardwood emissions from open fires, yielding 10 $g.kg^{-1}$ for particles and 115 $g.kg^{-1}$ for CO. Lipari *et al.* (1984) used the EPA Method 5 to test three hardwood species in an open fire, obtaining an average particulate emission of 9.71 $g.kg^{-1}$. Butcher and Ellenbecker (1982) sampled flue gases emitted from the combustion of oak using a technique in which gases were mixed with about four volumes of outside air prior to sampling. The particulate emission factor averaged 3.75 $g.kg^{-1}$, surprisingly low given the low charging rate and the type of test used. The CO emission factor averaged 110 $g.kg^{-1}$. Fels *et al.* (1990) listed various emission factors associated with woodsmoke from a literature review. Pooled average emission factors for stoves were 7.3 $g.kg^{-1}$ (particulates) and 135 $g.kg^{-1}$ (CO); pooled average factors for open fireplaces were 6.1 $g.kg^{-1}$ (particulates) and 41 $g.kg^{-1}$ (CO). Quraishi and Todd (1986) presented a similar review for particulates in closed woodheaters, from which an overall mean of 9.9 $g.kg^{-1}$ from 185 tests was calculated.

The burn rate of wood (controlled by the damper) is proportional to the temperature of the burn and the oxygen intake, and has been demonstrated to be one of the most important factors determining the chemical characteristics and rates of woodsmoke emissions (Edgerton *et al.* 1986). While the 'average' burn rate for open fires is about 10 $kg.hr^{-1}$ (Freeman and Cattell 1990), the burn rate in an ordinary woodheater has been estimated at 1.4 $kg.hr^{-1}$ (Barnett 1982, cited in Quraishi 1985a), 1.6 $kg.hr^{-1}$ (Kaarakka *et al.* 1989) and 2.6 $kg.hr^{-1}$ (Traynor *et al.* 1987; Daisey *et al.* 1989). Emission tests on closed woodheaters using high charging rates (> 4 $kg.hr^{-1}$) are therefore unrealistic given user behaviour associated with the operation of woodheaters. Burnet *et al.* (1986) used the EPA Method 5 to assess the combined effect of burn rate and firebox size on emission output from woodheaters. Using a standard firebox of internal volume 0.068 m^3, a particulate emission factor of 24 $g.kg^{-1}$ and a CO emission factor of 220 $g.kg^{-1}$ was obtained at a burn rate of 1.4 $kg.hr^{-1}$, much higher than the respective factors of 14 and 140 $g.kg^{-1}$ obtained at a burn rate of 3.2 $kg.hr^{-1}$. Quraishi *et al.* (1984) and Quraishi (1985a) used data from studies in which more realistic burn rates of less than 3 $kg.hr^{-1}$ were adopted, and calculated a mean emission factor of 21 $g.kg^{-1}$ for particles and 130 $g.kg^{-1}$ for CO in closed woodheaters, higher than those reported using generous burn rates at which combustion is more complete.

The first tests using *Eucalyptus* spp. (Todd and Quraishi 1986b) adopted the Condor method in a Burning Log Turbo 10 woodheater. An average particulate emission factor of 9.65 $g.kg^{-1}$ was obtained for *Eucalyptus* spp. with loads of about 11.1 kg; an average factor of 1.55 $g.kg^{-1}$ was obtained using loads of about 7.0 kg. Quraishi and Todd (1986) burnt split billets of *E. amygdalina* in a non-catalytic woodheater using the Condor method, obtaining an average particulate factor of 10.0 $g.kg^{-1}$. This is similar to the 8.2 $g.kg^{-1}$ reported by Quraishi (1987) for eucalypts, although the result was considered conservative because the woodheater model was cleaner burning than other comparable models. Many emission tests have since been conducted in Hobart using eight modern woodheaters, and while a typical emission factor for particulates from the current generation of wood heaters is 7 to 15 $g.kg^{-1}$ (Todd 1993) or 11 $g.h^{-1}$ (Todd 1990), some appliances have yielded up to 33 $g.kg^{-1}$ (56 $g.h^{-1}$) of particulates (Todd 1990).

Motor vehicles

Petroleum driven vehicles such as cars, trucks and buses emit many substances also found in woodsmoke. Most particles emitted from automobiles carry the same organic species and comprise a similar particle size distribution (mostly < 1 μm) to woodsmoke (Milne *et al.* 1984). Motor vehicle emission factors for particles and CO have been measured as part of a comprehensive inventory of emissions in the Port Phillip region of Victoria (Carnovale *et al.* 1991). An average emission factor of 25.8 $g.km^{-1}$ CO was reported for the movement of petrol powered cars, wagons and motor cycles in residential areas, while diesel vehicles including heavy vehicles contributed much less (~5 $g.km^{-1}$). Particulate emissions from petrol cars and wagons averaged 0.05 $g.km^{-1}$. Particles from diesel vehicles were 2.09 $g.km^{-1}$ (Carnovale *et al.* 1991). The Australian Environment Council AEC (1988) estimated a 30.7 $g.km^{-1}$ CO emission factor for petrol cars, although driving conditions were unspecified.

Coal-fired boilers

There are two boiler stations within the grounds of the University of New England, delivering a combined maximum 14 MW to heat the campus using hot water in convoluted pipes. No tests have been undertaken to assess emission rates from these boilers. Black coal is consumed at a rate of about 2 $t.hr^{-1}$ via travelling grate stokers during peak periods. Based on a substantial review of literature in which EPA Method 5 was adopted to assess particulate matter, USEPA (1985) provided an average emission factor for travelling grate stoker boilers of 4.6 $g.kg^{-1}$. Quraishi (1987) and Rau (1989) challenge EPA-5, suggesting that it under-estimates total emissions because it fails to account for condensable organic particles, gaseous in the stack (and subsequently not sampled) yet condensed into liquid droplets in the atmosphere. Quraishi (1985b) claims that EPA-5 accounts for 40-50% of total particles emitted. An emission factor of 10 $g.kg^{-1}$ equates exactly with the 20 $lb.ton^{-1}$ given by EPA (1977; cited in Dasch and Cadle 1989). Assuming a gross calorific value of 29.3 $MJ.kg^{-1}$ for black coal (Lyons *et al.* 1985), 10 $g.kg^{-1}$ is also equivalent to 0.293 $g.MJ^{-1}$, similar the 0.77 $lb.Btu^{-1}$ (0.33 $g.MJ^{-1}$) given in a 1979 report by USEPA (Hall and DeAngelis 1981).

USEPA estimated in 1979 the concentration of CO expelled from woodheaters at 3.46 $lb.Btu^{-1}$ (43.4 $g.kg^{-1}$) (Hall and DeAngelis 1981). AEC (1988) claims this to be much higher than CO emissions from coal-fired power stations. The author provided an average CO emission factor of just 2.5 $g.kg^{-1}$ for industrial coal combustion compared with 45 $g.kg^{-1}$ for coal burnt as a domestic fuel. USEPA (1985) report the same value for bituminous coal (2.5 $g.kg^{-1}$), while CO output from the combustion of black coal (anthracite) in coal-fired boilers was reported at just 0.3 $g.kg^{-1}$.

6. Woodsmoke assessment in Armidale

Introduction

Atmospheric dispersion is poor during cloudless winter nights in Armidale. The town is located in a shallow depression of relatively high elevation (range 960 to 1080 metres a.s.l.), sea breezes are absent and high pressure cells are dominant in winter, resulting in clear, calm and cold nights. These conditions create temperature inversions, caused by longwave radiation loss from the ground on cloudless nights (Linacre and Hobbs 1977) in which rapid cooling of the ground surface causes surface air to cool more quickly than the air above (Lynn 1976). Thompson (1970) evaluated the mesoclimatic characteristics of the urban floodplain environment in Armidale between October 1966 and September 1967 (365 days). A total of 204 temperature inversions were detected (56% of nights), in which the extreme minimum temperature on Dumaresq Creek was -7°C (the minimum temperature recorded in Armidale was -10°C in July, 1918). A maximum difference of 10°C was measured between the minimum night temperatures on the floodplain and the crest of North Hill, some 100 m higher in elevation, and the mean minimum temperature difference was 4.5°C (Thompson 1970).

An estimated 3500 air-tight wood heaters, 600 open fireplaces, 600 wood stoves, and 100 other wood appliances (section 2.4.1) release woodsmoke into the confined volume of Armidale's airshed during cold winter evenings, where it can be entrapped by a temperature inversion close to ground level. This results in overnight accumulation of smoke and formation of a 'brown cloud' enshrouding Armidale (Plates 1 and 2). The brown cloud problem is synonymous with particulate emissions from RWC (Dasch 1982; Stevens 1985), It degrades visibility and poses a potential threat to human health.

Application of the mass emission method

Table 1 lists the various assumptions associated with fuelwood utilisation during a 'typical' and 'extreme' winter night in Armidale. An estimated 57 t is used by Armidale residents during a typical winter evening, compared with 150.5 t during an extremely cold evening. Assuming an emission factor for woodsmoke particles of 15 $g.kg^{-1}$ from closed woodheaters and 10 $g.kg^{-1}$ from open fires (part 5), a total of 743 kg of particulates (69.7% from closed woodheaters and 30.3% from open fires) escape into the airshed during a typical night. This contrasts with a total of 2075 kg of particulates emitted during an extremely cold night (82.4% from closed heaters and 17.6% from open fires). Because of poor dispersal conditions associated with temperature inversions, woodsmoke accumulates in the air-shed during the evening. The rate at which it is lost through cold air drainage and particulate settling is unknown.

Plate 1.

Plate 2.

Woodsmoke pollution in Armidale (0730 hrs, 11-08-94)

Table 1. Assumed woodburning behaviour in Armidale during 'typical' and 'extreme' winter nights.

	Variable	'Typical' night	'Extreme' night
	Min. temp	2°C	-8°C
	Inversion layer	1 020 m a.s.l.	1 000 m a.s.l.
	Inversion volume	5.2 x 10^8 m^3	2.2 x 10^8 m^3
	Duration of inversion	15 hrs (5pm - 8am)	18 hrs (4pm - 10am)
	% contributing to pollution [1]	85%	75%
Wood heaters	No. used	2 000	3 300
	Duration of use [2]	5 hrs (5pm - 10pm)	8 hrs (4.30pm - 10pm; 6.30am - 9am)
	Loading rate	2.5 $kg.hr^{-1}$	3.5 $kg.hr^{-1}$
	Quantity consumed (per house)	12.5 kg	28 kg
	Quantity consumed (town)	25 t	92.5 t
Open fires	No. used	450	550
	Duration of use [2]	5 hrs (5pm - 10pm)	5.5 hrs (4.30pm - 10pm)
	Loading rate	10 $kg.hr^{-1}$	12 $kg.hr^{-1}$
	Quantity consumed (per house)	50 kg	66 kg
	Quantity consumed (town)	22.5 t	36.5 t
Wood stoves	No. used	400	450
	Duration of use [2]	5 hrs (5pm - 10pm)	8 hrs (4.30pm - 10pm; 6.30am - 9am)
	Loading rate	4 $kg.hr^{-1}$	5 $kg.hr^{-1}$
	Quantity consumed (per house)	20 kg	40 kg
	Quantity consumed (town)	8 t	18 t
Other	No. used	70	90
	Duration of use [2]	5 hrs (5pm - 10pm)	8 hrs (4.30pm - 10pm; 6.30am - 9am)
	Loading rate	4 $kg.hr^{-1}$	5 $kg.hr^{-1}$
	Quantity consumed (per house)	20 kg	40 kg
	Quantity consumed (town)	1.5 t	3.5 t

1. Some woodburning homes are located at comparatively high altitude where woodsmoke would either dilute in the warmer air above the inversion layer or slide into a rural fringe area.
2. Within period of temperature inversion only, and not including overnight smouldering during which time no additional fuel is charged.

Motor vehicle emission rates given by Carnovale *et al.* (1991) (part 5) are used in conjunction with a number of broad assumptions (Table 2) to determine particle and CO loadings from motor vehicles in Armidale. Total gross particulate loading during each two hour period is estimated to be 2.1 kg, representing 0.4% of that issued by RWC during a typical night, and 0.2% of that issued by RWC on a very cold night. Contribution of motor vehicles to particulate loading in the Armidale airshed is thus negligible. Total CO loading by motor vehicles during both periods (i.e. 4 hours; Table 2) is estimated to be 880 kg, equivalent to 45.6% of CO emitted by RWC on a typical evening (1930 kg) and 26.6% of CO emitted by RWC on a very cold night. Unlike particulates, CO emitted from motor vehicles increases the ambient night-time concentration significantly.

Table 2. Assumed vehicular use in Armidale during a winter peak periods (7-9 am and 5-7 pm)

Variable (cars and light trucks)	
Number of dwellings in Armidale	5700
Number of cars per dwelling	1.0
Mean distance per car per evening travelled in town [1]	3 km
Total travel distance in town [1]	17 000 km

Variable (Heavy diesel vehicles - trucks and buses)	
Estimated number	30
Mean distance per vehicle per evening travelled in town [1]	20 km
Total travel distance in town [1]	600 km

1. within the confines of the temperature inversion

The larger of the two University boilers is situated on an upper slope at an elevation of 1055 m a.s.l, and the top of the chimney stack is about 1090 m a.s.l. This boiler is likely to expel its emissions above the inversion layer. The smaller boiler is located close to Dumaresq Creek at an elevation of 995 m a.s.l. Its smoke plume has been observed on a number of cold winter mornings drifting east from the stack, losing altitude and dispersing rapidly into the morning brown cloud of Armidale. The boiler consumes a maximum 17 $t.day^{-1}$ of coal and delivers about 5 MW (18 000 $MJ.hr^{-1}$) during the peak period of 4 am to 11 am at a consumption rate of about 1.5 $t.hr^{-1}$. Assuming an emission factor of 10 $g.kg^{-1}$ for particles and 2.5 $g.kg^{-1}$ for CO (part 5), the corresponding emission rates for the two hour period 7 to 9 am are 30 kg and 7.5 kg. While CO emissions from the boiler station are thus negligible, peak particulate emissions on typical and extreme mornings represent 11.6% and 5.9% of the respective levels issued by RWC.

Woodsmoke concentrations

The concentration of woodsmoke particles within Armidale's airshed cannot be estimated using the mass emission method without quantifying the air-shed volume into which pollutants are emitted. This is complicated by mechanisms of cold air drainage in relation to temperature and topographic profile, as well as particulate settling rate and fuelwood-user behaviour.

EPA began monitoring air pollution in Armidale in April, 1995. An integrated nephelometer located on the roof of the public swimming pool complex recorded an index of light scatter (b_{sp}: 10^{-4} m^{-1}) every 2 minutes, from which 1-hr, 3-hr, 6-hr, 12-hr and 24-hr means were calculated. In conjunction with the nephelometer, a high-volume air sampler (located on the same roof) was operated intermittently from July, 1995. Simultaneous 3-hr readings from the nephelometer and high-volume sampler were obtained on 7 occasions. These were plotted and a regression relationship between b_{sp} and PM_{10} and was derived (Figure 1). The relationship was linear and highly significant ($P<0.0005$; $r^2=0.98$).

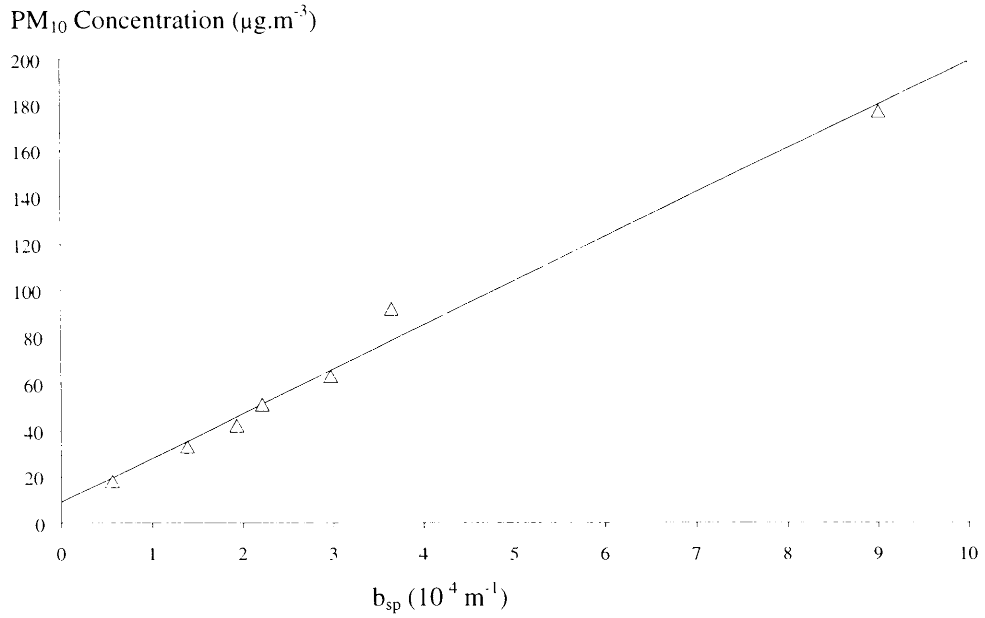

Figure 1. Regression equation and scatterplot depicting the winter relationship between bsp and PM_{10} in Armidale ($PM_{10} = 19.01*b_{sp} + 9.02$).

Figure 2 presents a running plot of diurnal mean and hourly maximum b_{sp} and PM_{10} and minimum diurnal temperature from 7 April to 30 August, 1995. The maximum hourly b_{sp} index ($10.15 \times 10^{4}.m^{-1}$) was recorded in the early morning of June 27 and was equivalent to a PM_{10} concentration of 202 $\mu g.m^{-3}$. The long-term average PM_{10} concentration over 140 days was 25.7 $\mu g.m^{-3}$. Similar to woodsmoke studies elsewhere, there was a negative correlation between minimum diurnal temperature and PM_{10} concentration.

An estimated 75% of maximum hourly PM_{10} levels, measured from 1200-1200 hr over 140 days, occurred in a 7-hr period between 1800-0100 hr. A further 10% occurred between 0600-0900 hr. Figure 3 shows the hourly variation in mean PM_{10} levels. For the 35 evenings in which temperatures fell below 1°C (top line in Figure 3), PM_{10} concentrations increased from near background levels of 10 $\mu g.m^{-3}$ at 1600 hr to about 40 $\mu g.m^{-3}$ at 1800 hr. A large number of residents would have ignited their woodheaters during this period, coinciding with the formation of a temperature inversion. The rate of PM_{10} accumulation slowed after 1800 hr, reaching about 60 $\mu g.m^{-3}$ by 2100 hr. It increased again between 2100 and 2300 hr to a peak level of about 85 $\mu g.m^{-3}$, coinciding with the closing of dampers before retirement. Peak levels were maintained for two hours, then PM_{10} subsided to 37 $\mu g.m^{-3}$ by 0500 hr. There was a second, less prevalent peak at 0700 hr, coinciding with the re-ignition of woodstoves around breakfast time. Inversions were not active between 0900 and 1600 hr and PM_{10} levels were maintained at low levels. The PM_{10} fluctuation has been observed in other wood-burning towns. Typical night-time levels in Waterbury, Vermont exceeded afternoon levels by 5- to 10-fold (Sexton *et al.* 1984a), and peak 3 to 6 hr concentrations during evenings in Portland, Oregon contributed up to 50% of the mean 24-hr concentration (Khalil *et al.* 1983).

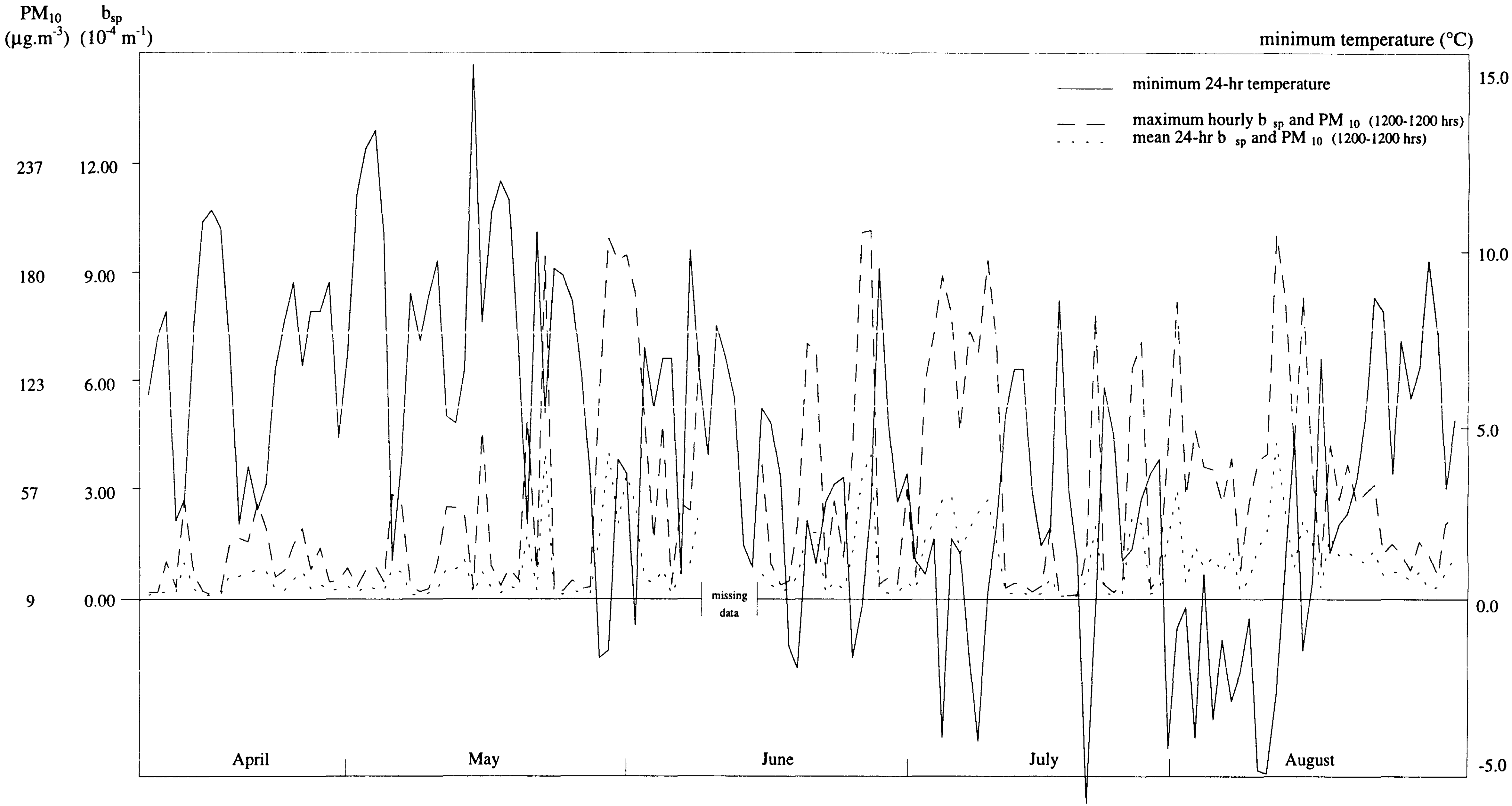

Figure 2. Moving average 24-hr PM_{10} and b_{sp}, maximum hourly PM_{10} and b_{sp}, and minimum air temperature recorded at Armidale from 7 April to 30 August, 1995.

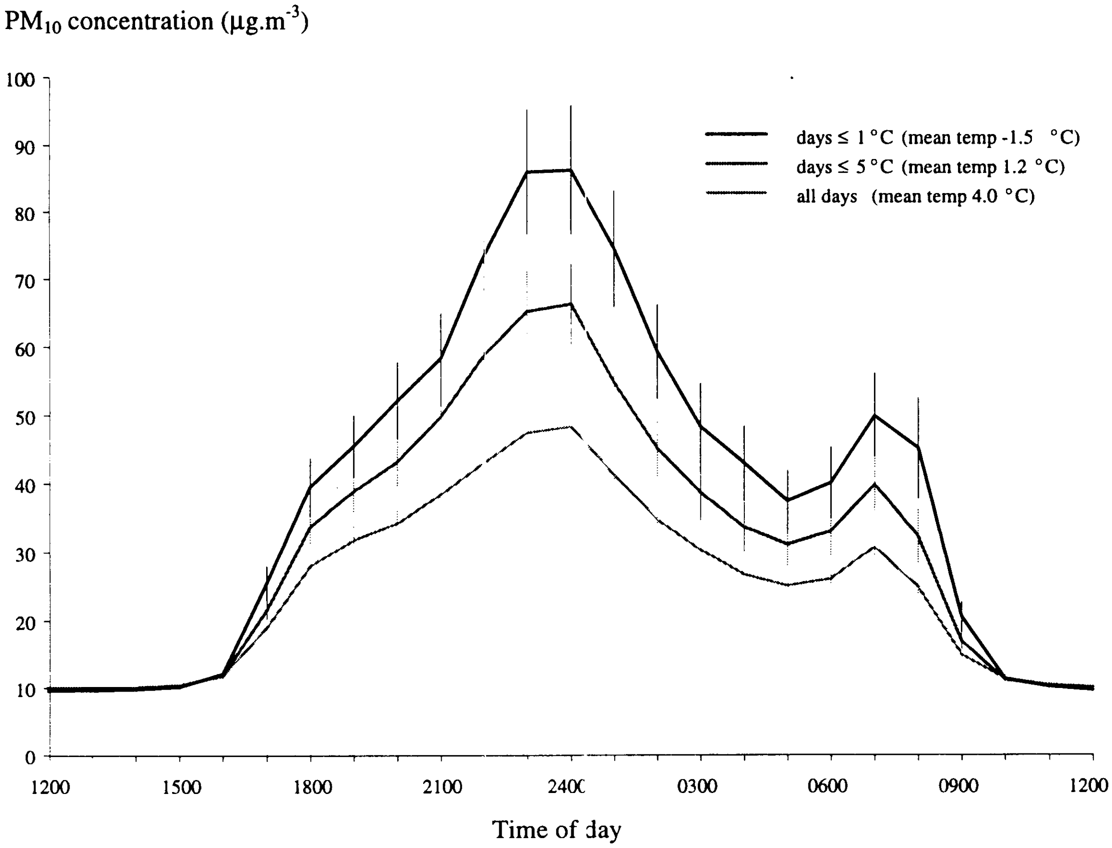

Figure 3. Hourly variation in 1-hr PM_{10} concentrations for all days, days with a minimum recorded temperature ≤ 5°C, and days with a minimum recorded temperature ≤ 1°C in Armidale in winter, 1995.

Table 3 provides a monthly summary of PM_{10} levels recorded in autumn and winter, 1995. Mean 24-hr concentration was similar during the 3 winter months (between 27 and 30 $\mu g.m^{-3}$), and less during the comparatively warmer autumn months of May (23.6 $\mu g.m^{-3}$) and April (15.3 $\mu g.m^{-3}$). Almost 11% of all 24-hr periods within the 5 months had a mean PM_{10} level in excess of 50 $\mu g.m^{-3}$, with almost 20% of these in June and July. The mean concentration of PM_{10} was maintained > 50 $\mu g.m^{-3}$ during a cold 135 hr period from 28th April to 3rd May. According to a review of health effects of fine particles (section 3), these results suggest the need for a more detailed assessment of the health implications of woodburning in Armidale.

Table 3. Summary of PM_{10} concentrations in Armidale in winter, 1995.

		Months					
		April	May	June	July	August	All
No. hours recording		563	744	618	744	744	3413
Min. diurnal	mean	6.4 ± 0.6	7.1 ± 0.7	3.3 ± 0.7	1.6 ± 0.6	2.0 ± 0.8	4.0 ± 0.4
temp. (°C)	min	2.0	-1.7	-2.0	-5.7	-4.9	-5.7
	mean 24-hr	15.3 ± 1.1	23.6 ± 3.7	27.4 ± 4.3	28.5 ± 3.6	29.6 ± 2.8	25.7 ± 1.6
	max. 1-hr	59.4	197.7	202.0	186.1	199.8	202.0
PM_{10} ($\mu g.m^{-3}$)	max. 3-hr	53.2	182.6	190.0	152.7	187.2	190.0
	max. 6-hr	50.4	170.4	179.2	143.5	157.7	179.2
	max. 12-hr	39.2	145.1	163.4	110.7	150.2	163.4
	max. 24-hr	26.9	85.2	90.4	67.6	93.6	93.6
No. (and %)	1-hr	5 (0.9)	81 (10.9)	108 (17.5)	138 (18.5)	116 (16.0)	448 (13.1)
of recordings	3-hr	4 (0.7)	85 (11.4)	105 (17.0)	141 (19.0)	110 (14.8)	445 (13.0)
exceeding	6-hr	1 (0.2)	79 (10.9)	106 (17.3)	148 (19.9)	106 (14.2)	440 (12.9)
50 $\mu g.m^{-3}$	12-hr	0	77 (9.9)	102 (16.8)	154 (20.7)	85 (11.4)	418 (12.3)
*	24-hr	0	86 (11.6)	110 (18.5)	147 (19.6)	48 (6.5)	391 (11.5)
max. period in which mean $PM_{10} > 50$ $\mu g.m^{-3}$ (hr)		0	75 (28-31 May)	72 (25-27 June)	70 (4-7 July)	112 (10-15 Aug.)	135 (28Apr-3May)
max. period in which hourly $PM_{10} > 50$ $\mu g.m^{-3}$ (hr)		2 (20-21 Apr.)	15 (28-29 May)	15 (26-27 June)	11 (4-5 July)	15 (10-11 Aug.)	15 (May.Jun.Aug)

* 3-hr, 6-hr, 12-hr and 24-hr periods overlap within each other by 1 hour increments

The Armidale results can be compared with those from several other wood burning towns and cities experiencing winter inversions. Sexton *et al.* (1984a) measured total suspended particles (TSP) in the small rural township of Waterbury, Vermont (pop. 2000), obtaining a maximum value of 80 $\mu g.m^{-3}$, and predicting a maximum 120 $\mu g.m^{-3}$ under worst conditions. Waterbury contained only 350 houses at the time of study, of which 28% used wood as their main form of energy. In Elverum, Norway (pop. 10 000), a maximum level of 101 $\mu g.m^{-3}$ was recorded for the fine fraction (FF < 2.5 μm diameter) in 1982 (Ramdahl *et al.* 1984). Despite a 65% contribution by RWC, wood provided just 3% of net annual domestic energy demand in Elverum. A maximum 209 $\mu g.m^{-3}$ was recorded in Juneau, Alaska, over a 12-hr night-time period, to which RWC contributed 82% (Watts *et al.* 1988). A maximum PM_{10} concentration of 150 $\mu g.m^{-3}$ was recorded in Hobart, with distinct peaks in evening and morning (Usman 1988 cited in Forestry Technical Services and University of Tasmania FTS and UT 1989), and levels of up to 250 $\mu g.m^{-3}$ were recorded in Launceston (pop. 95 000) in July, 1991, where almost 70% of residents use fuelwood (Todd 1992).

The worst 24-hr average particulate concentration for a housing density of 400-500 km^{-1} over an area of 4 km^2 or more, in which the entire heating load is carried out by RWC, is hypothesised by Butcher and Sorenson (1979) to be 100 $\mu g.m^{-3}$. While RWC in US centres such as Boise, Idaho (Core *et al.* 1984), Albuquerque, New Mexico (Stevens 1985) and Eagle River, Alaska (Myers 1985) contribute no more than 100 $\mu g.m^{-3}$ to total 24-hr TSP, Quraishi *et al.* (1984) cited literature which observed that 1980 particulate levels in Missoula, Montana (for which woodsmoke was mainly responsible) often violated national ambient air quality standards, and occasionally exceeded 500 $\mu g.m^{-3}$. School children and older citizens with chronic obstructive pulmonary disease exhibited significant lung dysfunctions during winter months. The maximum 24-hr level recorded in Armidale was 93.6 $\mu g.m^{-3}$ in early August (Table 3). It is probable that maximum levels exceed 100 $\mu g.m^{-3}$ in the lower-elevation eastern suburbs of town where woodsmoke buildup is visually greater

7. Remedial measures

Introduction

The basic objective of air pollution control is to restrict the concentration of pollutants in ambient air to levels that will not adversely affect the health, well-being or welfare of the community (Australian Environment Council and National Health & Medical Research Council AEC and NHMRC 1986). There are several ways of achieving this. Following the infamous 1952 smog which killed over 3500 people (Ministry of Health 1954 cited Anon. 1970), the city of London established smoke control areas in which domestic combustion of coal and wood was outlawed (Anon. 1970). Various South Korean cities have also banned woodfires to reduce pollution (Annandale *et al.* 1983). A common practice in the US is to enforce restrictions on firewood use during periods of poor dispersion, as in Juneau, Alaska (Watts *et al.* 1988), or voluntary bans, as in Missoula, Montana (Huber *et al.* 1985). Legislation has been enacted in Oregon to limit the emissions from woodburning homes (Quraishi and Todd 1986), and residents in Amherst, Massachusetts, require a licence to install a woodstove, with heavy fines for subsequent improper use (Miller and Miller 1989). Local authorities have restricted the number of wood-burning appliances installed in new buildings and limited the amount of wood burnt over a given period of time in Vail, Colorado (Sexton *et al.* 1984a) and in Great Neck Plaza, New York, woodstoves have been banned altogether (Boerner 1987).

While direct prohibitive measures have an immediate impact on the woodsmoke problem, they ignore the socioeconomic benefits of firewood energy such as low cost, renewability and sustainability, and decentralised supply. Quraishi *et al.* (1984) and Quraishi and Todd (1986) advocate a positive rather than retrograde strategy for Australia, including design of low emission heaters, introduction of emission standards for new appliances, and use of catalytic converters. In the absence of policy driven restrictive measures which obstruct directly the consumer's freedom of choice, woodsmoke control and prevention is possible in Armidale through adoption of a strategy of user education and extension in conjunction with a major restructuring of the firewood supply industry.

Legislative control and prevention in Australia

Streeton (1990) reviewed the international literature on air pollution and concluded that little is known in Australia of the wide range of pollution control activities underway in the northern hemisphere. In terms of woodsmoke pollution, for example, there was neither any national emission standard at federal level nor any regulation at state or local level as late as 1990. Initiative for change in some Australian states occurred largely as a result of US research and development in woodsmoke control, where several towns which were attaining pollution standards in the 1970s, as outlined by the National Ambient Air Quality Standards, were consistently violating the same standards a decade later due to an upsurge in the domestic use of fuelwood. Areas exceeding standards in the US are designated 'non attainment areas', and require special measures including installation of pollution retarding controls for existing sources (retrofit catalysts or woodstove replacement) and adoption of maintenance and inspection programmes (Quraishi 1987).

A recent surge in the number of public complaints in wood-burning centers such as Canberra (ACT) and Hobart (Tas), in conjunction with the publicity woodsmoke was receiving overseas, led to national recognition of the problem, and a joint Australian and New Zealand standard test method was developed for air-tight, non-catalyst woodheaters in 1992. Woodstove manufacturers in Tasmania, Victoria, ACT, and more recently NSW, are now obliged by government to obtain a certificate of compliance for any new model manufactured locally or imported into the state for sale. The model must satisfy conditions of Australian Standard AS4013, in which particulate emission factors for non-catalytic stoves must not exceed 5.5 $g.kg^{-1}$ (Todd 1993).

Unlike emission standards, the suite of air quality or health standards associated with chemicals released by RWC were developed in the northern hemisphere. For example, the USEPA requires that the 24-hr level of PM_{10} does not exceed 150 $\mu g.m^{-3}$ more than once a year, and the mean annual concentration of PM_{10} does not exceed 50 $\mu g.m^{-3}$ (Simpson and Xu 1991). Quraishi (1987) and Streeton (1990) argue that adoption of overseas standards is inappropriate because of major cross-country differences in firewood species, appliance types, heating requirements, user habits, climatic conditions and topographic situations. They argue that air pollution standards should be developed specific to Australia. Streeton (1990) suggests a maximum acceptable 24-hour average of 120 $\mu g.m^{-3}$ for fine particles and the National Health and Medical Research Council stipulates an annual mean of 90 $\mu g.m^{-3}$ for TSPs. AEC and NHMRC (1986) recommended an annual mean standard of 90 $\mu g.m^{-3}$ for TSP and an eight hour average of 10 $mg.m^{-3}$ for CO, not to be exceeded more than once a year. These recommendations might well be reconsidered in view of recent research into the health effects of prolonged exposure to fine particles (Dockery *et al.* 1993; Koenig *et al.* 1993; Schwartz *et al.* 1993; Pope *et al.* 1995). A maximum 24-hr PM_{10} concentration of 50 $\mu g.m^{-3}$, not to be exceeded more than one a year, is expected to be introduced shortly in the UK (Hamer and MacKenzie 1995).

Improved stove design

The effectiveness of catalytic combustors has been the subject of much debate within the fuelwood community. Adapted from its automobile counterpart, the woodstove catalyst comprises a ceramic honeycomb substrate coated with a noble metal catalyst, palladium or platinum (Quraishi *et al.* 1984).

Placed directly in the exhaust flow, it works by increasing stove efficiency and reducing the ignition temperature of volatile hydrocarbons and CO, thus reducing creosote deposition and ambient air pollution. Whilst many advocate the use of catalysts, particularly in the US (Gay 1984; Keough 1986; Burnet *et al.* 1986), others are more cautious, stating that inherent problems such as high cost, catalyst deterioration and periodic replacement, and deactivation if anything other than wood is burnt, make the combustor unattractive (Pilcher and Ghajar 1985; McCrillis 1990). Retrofit devices can be added to older woodstoves, although these are generally unsatisfactory due to excessive smoke spillage during charging (McCrillis 1990). Although very popular in US, catalytic woodstoves and equivalent retrofit devices are not currently manufactured in Australia (J Todd 1993 pers. comm.). If primary combustion is good, there can be insufficient unburnt gases to sustain secondary combustion and a catalyst has only limited benefits (Todd 1993).

Several other woodstove technologies are available. Inclusion of a secondary combustion chamber inside the stove has been shown to reduce emissions (Spengler and Cohen 1985). A secondary air inlet pipe passing through the fire itself before entering the combustion chamber can enhance wood combustion (Roper 1983). Löfroth *et al.* (1986) found that by using the downdraft principle with 2-stage burning using secondary air, pyrolysis products can be reduced by up to 90% compared with single chamber units. The State Pollution Control Commission SPCC (1986) indicated a possible 50-80% reduction in particles with the use of a secondary combustion chamber. Quraishi (1985a) cited reports showing that side draft rather than updraft stoves emit less smoke.

A thermal storage mass (a thick 3-sided ceramic or brick structure in which the stove is encased) enhances combustion, reduces pollution and offers protection from the hot exterior walls of the stove (Pilcher and Ghajar 1985). Another beneficial design feature of some slow combustion stoves is that the damper and air inlet pipes must be opened completely to enable the firebox door to be opened for refuelling (SPCC 1986). Internal dimensions of the firebox are also important. The optimum internal height : diameter ratio for any sized heater is 0.35 (Bhatt 1990a,b), although higher rates of emission are likely from bigger units (Burnet *et al.* 1986). Other innovations in non-catalytic stoves include mechanical draft, continuous fuel-feed stoves and wood-pellet burning units (Burnet *et al.* 1986).

The effectiveness of woodstove improvement programs has been illustrated by various authors. McCrillis (1990) cited literature which found PM_{10} concentrations in excess of 110 $\mu g.m^{-3}$ in the small town of Creste Butte, Colorado (pop. 800), 75% of which was attributed to woodsmoke. In the two years after introduction of a stove replacement strategy, the maximum concentration recorded was 39 $\mu g.m^{-3}$. Todd (1992) estimated that with regulation in Launceston, the total particle emission could drop from about 1800 t in 1992 to 1300 t by 2010. A combination of community education and woodstove regulation could reduce emissions to 750 t by 2010 (Todd 1992).

User education

The firewood consumer is generally unaware of the various ways in which to reduce total emissions, and user education is arguably the best preventative means. Findings of a comprehensive indoor emission study by Sexton *et al.* (1984b) indicated that airtight woodstoves can be installed, operated and maintained in such a way that direct release of particles to the indoor environment is negligible. Todd (1993) suggested that a public education campaign alone could reduce emissions by more than half, and with the added introduction of woodheater standards, emission rates could drop by a factor of five (from 15 to 3 $g.kg^{-1}$). If such procedures were adopted in Armidale, a significant abatement of outdoor pollution would be achievable without measures of prohibition. The keys to reducing emissions are correct stove operation and fuelwood selection.

A significant quantity of particulate matter is typically released when the fire is started. This is due mainly to low initial temperatures as well as flame quenching (Todd 1990), although any combination of oversized pieces (Dasch 1982; Quraishi 1985a), under-seasoned wood (Allaby and Lovelock 1980; Quraishi *et al.* 1984; Burnet *et al.* 1986), oxygen deficiency and lack of turbulence (Roper 1983; Spengler and Cohen 1985; Todd 1990) and poor initial stacking (Hall and DeAngelis 1981) can increase emissions. For complete combustion of dry wood, Pilcher and Ghajar (1985) argued the need for high combustion-zone temperatures during the beginning of the burn cycle when volatile gases are released. Since particulate emissions are initially high and decrease rapidly over time, it is important to acquire a hot burn as soon as possible (Dasch 1982; Roper 1983; Todd and Quraishi 1986a). In this respect, the correct fire-starting procedure is essential in any education program.

Todd (1990) listed the ignition temperatures of some gases released from carbonisation: CO at 590°C; CH_4 (methane) at 650°C; $CH_3.COOH$ (acetic acid) at 540°C; and HCHO (formaldehyde) at 430°C. If gas temperatures in the firebox are maintained at overnight 'cool burn' levels of 250-300°C (Edgerton *et al.* 1986), many such gases including VOCs will be expelled into the outside atmosphere or deposited as creosote on the inside of the flue. Work by Hayden and Braaten (1981,1982) (cited in Quraishi 1985a) indicated that emission rates were reasonably insensitive to burn rates above a critical burn rate of 4 $kg.hr^{-1}$. However, typical wood consumption in Australian households is below 4 $kg.hr^{-1}$ (Quraishi 1985a), resulting in higher than necessary POM and CO emissions. The essential message for the fuelwood consumer is that increasing a woodstove's efficiency by reducing oxygen supply (thus reducing combustion temperature) will inevitably increase emissions. However, the usual marketing ploy instituted by woodstove manufacturers is "load the fire up, turn the stove down, keep the house warm all night, and don't worry about relighting in the morning". The tradeoff between efficiency and emissions is pivotal to the woodsmoke dilemma; the harsh reality is that the marketing of woodstove efficiency must be relaxed and more wood should be burnt to curb emissions! Opening the stove damper before retirement to allow complete combustion of the final load, then relighting in the morning is clearly a better option in terms of emission reduction. It is also probably the most difficult to implement.

The rate at which a fire is charged with wood affects the oxygen-fuel ratio in the combustion zone and greatly influences emission factors (Spengler and Cohen 1985). The authors found that a typical air-fuel ratio for optimum burning was 12:1 by mass. This conforms with other work (Quraishi 1985a,1987; Burnet *et al.* 1986; Todd and Quraishi 1986a) demonstrating that high loading densities increase emissions significantly because of a rapid decrease in combustion temperature and exposure of more wood to pre-burn pyrolysis. Quraishi (1985a) referred to several studies which show that larger (and consequently fewer) charges result in a near doubling of emission rates at the same burn rate. The best technique is frequent addition of less timber upon a very hot bed of embers, although constant stoking is undesirable (Traynor *et al.* 1987).

Fuelwood characteristics

The selection of appropriate combustible material is essential for reducing emissions. The potential health impacts of burning treated timber were discussed in section 3. Similar problems could arise from repeated combustion of spent chemical containers and plastic waste, especially in cities such as Sydney, where outdoor incineration of domestic refuse is outlawed.

Timber species can have a significant effect on emission composition. Softwoods typically contain more extractable organic matter and lignin than hardwoods (Ragland *et al.* 1991), and emit more than twice the concentration of fine particles as hardwoods under controlled cool burn conditions (Edgerton *et al.* 1986). A catalytic stove burning pine has been observed to emit more PAHs than a conventional stove burning oak (McCrillis *et al.* 1992) and the particulate emission factor for pine is roughly twice that of eucalypt (Todd and Quraishi 1986a). Such is the concern for burning softwood that some stove manufacturers have been known to cancel warranties if softwoods are burnt (Todd 1986).

Although bark possesses a higher calorific value than timber (Gough *et al.* 1989), bark combustion may increase emissions due to its relatively high proportion of chemical extractives or minerals (Browning 1967; Ragland *et al.* 1991). Bark contains 2-6% ash content with slightly more carbon and less oxygen than wood (Lyons *et al.* 1985; Bootle 1983), and because ash particles are released during char combustion (Ragland *et al.* 1991), particulate emissions could be higher from bark than from wood. The bark of *Acacia* spp. and *Pinus radiata* contains a high polyphenol concentration, that of *E. sideroxylon* has a high tannin and polyphenol level, and that of *E. viminalis* contains 20% extractives, about 10 times as much found in the adjacent xylem (Hillis 1984b). Other disadvantages of bark retention include a reduction in seasoning rate (section 8.2.6) and transportation of nuisance invertebrates from forest to household (Todd and Horwitz 1990).

Most literature contends that timber density is inversely correlated with emission rate. Cedar was shown to emit twice the amount of aldehyde as red oak under similar burning conditions (Lipari *et al.* 1984); the air dry density of cedar is about half that of oak (Bootle 1983). Higher levels of PAHs and mutagenic activity have been observed from combustion of 'lower quality' scrap wood, such as briquettes made of woodchips and building waste (Nielson *et al.* 1992). Such findings are not universal. Groves and Chivuya (1989) observed subjectively the smoking patterns of low density species (*P. radiata* and *A. melanoxylon*) and high density species (*E. blakelyi* and *E. melliodora*), concluding that the latter, which proved more difficult to ignite, were very smoky during early stages of combustion. To reduce emissions at all stages of combustion, a fire might thus be ignited and maintained with low density, rapidly burning species (such as *Acacia*) in early development, until a coalbed is formed to accommodate the addition and ignition of high density billets, with which the fire should be charged occasionally until left to die.

Opinion is divided over the optimum moisture range for firewood, although the general consensus is that well seasoned wood is best. Spengler and Cohen (1985) cited literature which found that the lowest proportion of unburnt emissions (10%) resulted from combustion of wood with 15 to 25% moisture content. Quraishi (1985a) and Burnet *et al.* (1986) specified 20-25% as optimal, with higher moisture contents increasing emissions because of the greater amount of heat required to dry fuel (thus lowering firebox temperature), and lower moisture contents increasing emissions because volatile gases are generated at a faster rate than can be efficiently combusted (Burnet *et al.* 1986). With the added problems of high ignition temperatures and low combustion efficiency and heat output, there is a strong case for seasoning wood before it is burned (Groves and Chivuya 1989; Burley and Plumptre 1985; Lyons *et al.* 1985).

Firewood size is an important factor in terms of starting and maintaining the fire. Smaller pieces are more desirable as they have a shorter distance for pyrolysis products to diffuse, a larger surface area to mass ratio, and a reduced heating time (Quraishi 1985a). Lyons *et al.* (1985) suggested that pieces be chosen so that individual voids between pieces do not resist the passage of combustion air. The authors recommended a minimum fuelwood diameter of 12 mm and a diameter of 17-33% of the firebed depth. Quraishi (1985a) cited literature showing that heat transfer along the grain is twice that across the grain, emphasising the added desirability of splitting wood longitudinally before combustion. Groves and Chivuya (1989) reinforced the argument by claiming that smaller pieces can be seasoned more rapidly if protected from rain.

To curb emissions and improve home heating, it appears from the literature that longitudinally split pieces of high density, air-dried hardwood are optimal for use as fuelwood in domestic woodheaters. Ironically, many woodburning towns of eastern Australia are well endowed with fuelwood resources which meet these specifications. Evidence suggests that the combustion of bark of certain species should be avoided.

Modifications to fuelwood supply system

Access to premium quality fuelwood is fundamental to the issue of air quality. Adequately dried and split, local Armidale timbers provide excellent combustible material both in terms of heat output and woodsmoke control. Yet 15% of firewood consumed each year (over 2000 t) is inferior quality white gum, offcuts, pine, or scrap timber (Figure 2.8) which is likely to expel a disproportionate quantity of PAHs (Nielson *et al.* 1992). To ensure that residents are receiving a suitable quality (and quantity) of firewood, the industry must be made accountable for fuelwood sales (Morse 1985b; Wall and Reid 1993), eliminating the present situation in which customers are virtually at the whim of the wood merchant. Virtually all firewood deliveries in Armidale are underweight, some by as much as 50% (Table 2.2), and many orders contain inferior quality fuelwood, either as low grade species or semi-green or decomposing pieces. Any effort to educate residents on correct burning procedure must occur in conjunction with delivery of appropriate firewood. The silvicultural component of fuelwood supply entails the selection of suitable trees from stands of local forest (Chapter 8) or for farm plantations (Chapter 9). In both cases, trees would be felled, transported to a fuelwood storage facility, split and possibly debarked, allowed to season over 1-2 years, and sold to urban residents in due course. The present problems of rotten timber, inferior species, undersized loads, felling of trees in sensitive areas and habitat destruction would be avoided while the major problems inherent in fuelwood use - air pollution and forest depletion - would be addressed simultaneously.

Charcoal production

Charcoal is a form of carbon obtained by the incomplete combustion (or pyrolysis) of wood. It is manufactured in large kilns using a limited supply of air, sufficient to remove volatile gases and tars but insufficient to oxidise carbon (Bootle 1983). Charcoal is an attractive source of fuel. It has a calorific content of similar to that of coal and coke (range 30-32 $MJ.kg^{-1}$; Davidson 1987), a lower transport and handling cost than wood (Keita 1987), and it burns relatively freely of smoke (Burley and Plumptre 1985; SPCC 1986). The conversion efficiency of wood to charcoal must be questioned, however, since 3 t of wood produces about 1 t of charcoal (Davidson 1987). Development of a charcoal production centre outside town, with the objective of producing and selling bulk charcoal to domestic users, offers a partial solution to the woodsmoke problem, although the dirty nature of charcoal, like coal, could prove socially unacceptable to many.

Other controls

No obligation has ever existed on fuelwood users to install heaters of a standard quality in Armidale. This creates a serious impediment to emission reductions because inferior stoves continued to be used. While a successful emissions program could include retrofitting existing wood heaters with catalysts (Roper 1983), another avenue is offering a tax incentive or rate reduction to residents who replace old stoves. In France and Switzerland, home insurance premiums are adjusted according to stove type and creosote accumulation (Roper 1983).

The possibility of offset measures could also be explored, where other polluters pay for their own emissions by funding a widespread replacement of old woodstoves with cleaner burning units, thus reducing total emission loaded into the atmosphere (Roper 1983). Offset measures could be undertaken in Armidale through a small levy on motor vehicle registration, where vehicles are a significant source of airborne CO. The University of New England might similarly pay for its right to emit PM_{10} from its coal-fired boilers in preference to upgrading its pollution control facilities.

Emissions can be reduced by various other means. For example, flues located on outside walls emit more woodsmoke as a result of lower air turbulence caused by greater heat loss from flue to outside air (McCrillis 1990). No data are available on the proportion of Armidale flues located on outside walls, but building specifications could incorporate compulsive inside flues. Building specifications could also improve thermal efficiency of homes by insulation and more appropriate house design, a goal actively pursued by Armidale City Council. Limiting the number of woodheaters installed in households and other buildings (hotels, models, pubs, restaurants) to one has been undertaken in areas of Colorado (Huber *et al.* 1985). Formation of the Australian Solid Fuel and Wood Heating Association (ASFWHA) in 1984 was a positive step, bringing together over 500 manufacturers, distributors, retailers and service industries (Anon. 1990), and playing a major role in the development of the Australian Standard for both woodstove safety and installation (AS2918) and woodstove emissions (AS4013). Finally, clear operation procedures should be published and distributed to relevant Government agencies and the public at large. In addition to the outlining of appropriate burning procedures and fuel selection discussed above, pamphlets should clarify other issues such as the avoidance of burning domestic refuse and treated timber, cleaning stoves regularly. periodically testing stoves for leaks or faults, and stacking fuelwood in sheltered, well ventilated positions. An education campaign is being devised by Armidale City Council at present, with the intention of halving by winter 1997 the number of days the 24-hr PM_{10} concentration exceeds 50 $\mu g.m^{-3}$.

8. Conclusions

Emission inventory and air-sampling conducted in Armidale in winter 1995 shows that RWC contributes up to 95% of wintertime particulates, and poses a threat to human health in the town. Peak particle concentrations exceeded 200 $\mu g.m^{-3}$ and mean 24-hr concentrations exceeded 50 $\mu g.m^{-3}$ on several occasions with a maximum of about 94 $\mu g.m^{-3}$. Various remedial measures are suggested in preference to wood burning prohibition. These include woodstove compliance testing, user-education on woodheater operation, and regulation of the fuelwood industry to ensure the distribution of well seasoned timber.

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