BIOMASS OF BLACKBUTT (*Eucalyptus pilularis* Sm.)

FORESTS ON FRASER ISLAND

BY

Grahame Barry Applegate
B.Sc.(For.) A.N.U.

A thesis submitted as partial requirement for the degree of Master of Natural Resources, University of New England Armidale. April, 1982.



FRONTISPIECE

Pole stage *Eucalyptus pilularis* Sm. on Fraser Island

ABSTRACT

This study was undertaken to estimate the biomass within defined confidence limits of the blackbutt (*Eucalyptus pilularis* Sm.) forests on Fraser Island. The blackbutt forests grow on nutritionally poor siliceous sands and their productivity is dependent on the cycling of nutrients and the degree to which outputs of nutrients are balanced by inputs. Commercial forestry is undertaken in these forests, and the silviculture practised presupposes that the forests will maintain productivity.

The initial step to assess the effects of these practices was to quantify the biomass of all the plant material in the forest. Particular emphasis was placed on the biomass estimation of the plant components (foliage, branches, stem, roots) and stand fractions (trees, understorey, litter). In order to do this, three sites were chosen which were representative of a regeneration forest — at sapling stage (Wabby: age 14 years), a pole forest (McKenzie: aged 45 years), and an old growth forest (Deep: age ≈500 years).

By the development of a sound mensurational base, and with the aid of regression analysis, the biomass of the large tree component, including large roots, was estimated. A harvest technique was used to estimate small trees, understorey and litter, while fine roots, medium roots and dead organic matter below ground was estimated using a coring and monolith technique.

The biomass and standard error are presented for the tree components of each species and by stand fraction on the three sites.

There was a considerable difference between the biomass of the living trees on the three sites. This difference and variability was due, in part, to an age difference and as a consequence of the treatment on the sites.

The following results are presented in tonnes per hectare and the standard error has been expressed as a percentage of the mean.

The live large trees on Wabby weighed 76 t ha^{-1} ± 5%; McKenzie, 265 t ha^{-1} ± 2%; Deep, 1702 t ha^{-1} ± 34%.

Although the understorey biomass on the sites was considerable, (Wabby 1.6 t ha^{-1} ± 16.9%; McKenzie 2.4 t ah^{-1} ± 11.9%; Deep, 1.3 t ha^{-1} ± 14.8%) the contribution it made to the overall biomass on each site was small.

The litter (<10 cm dia.) on the forest floor on McKenzie was 16.1 t ha^{-1} ± 5.9%, and was largest on the Wabby site (22.4 t ha^{-1} ± 6.4%) and smallest on Deep (6.7 t ha^{-1} ± 28.1%). Even though McKenzie had the greatest, large litter biomass (138 t ha^{-1} ± 42%) the sites of Wabby and Deep contained 32 t ha^{-1} ± 82% and 40 t ha^{-1} ± 68% respectively.

The distribution of fine roots showed that, instead of being concentrated in the surface layers, they peaked at 20 - 60 cm below the surface on all three sites. A similar trend was evident for the medium roots. The biomass of the dead organic matter however, showed a peak in the top 60 cm on Wabby and McKenzie and tapered off at 150 cm. Deep, on the other hand, showed a peak between 20 and 60 cm and tapered off at 150 cm.

The total above ground biomass of the Wabby, McKenzie and Deep sites was 305 t ha^{-1} ± 40.6%; 460 t ha^{-1} ± 12.8%; 1784 t ha^{-1} ± 32.3% respectively, while the total forest biomass on the three sites was 413 t ha^{-1} ± 30.0%; 639 t ha^{-1} ± 9.3%; 1996 t ha^{-1} ± 28.9%.

ACKNOWLEDGEMENTS

Grateful acknowledgement is made to my supervisors, Associate Professor, Bryant Richards who with Dr. Jim Charley provided the opportunity to undertake this project, and to Dr. Ian Bevege, for his continued guidance and supervision, particularly while undertaking the research on Fraser Island.

The Forestry Department of Queensland made the study sites available and provided much logistic support without which the study could not have been undertaken.

The help of various staff members of the Department is acknowledged — the Maryborough District and in particular, the Fraser Island staff including Messrs. D. Lohse, D. Gordon, C. Nielsen and P. Lehman as well as the workshop personnel; in Brisbane, staff in the chemistry laboratory, the library, drafting office and the very helpful staff at the Indooroopilly Forest Biology Laboratory.

Particular thanks must go to Marks Nester for the time he spent computing data as well as his patience and willing assistance with computing problems.

Thanks also goes to the botanists of the Queensland Herbarium, who not only identified the species found on the three sites, but provided much encouragement and advice for my study of the flora of Fraser Island.

A very special thanks must go to my wife, Gaye, for her valuable assistance in the field and with typing the draft of this thesis as well as her understanding and patience during this entire project.

To my parents, sincere thanks for typing and reading this manuscript and for their continued supportive help and encouragement throughout my academic career.

The project was funded by the Rural Credits Development Fund of the Reserve Bank of Australia which is gratefully acknowledged.

UNITS OF MEASUREMENT AND ABBREVIATIONS USED

Basic Unit	Symbol
metre	m
square metre	m^2
cubic metre	m^3
gram	g
kilogram	kg
hectare	ha
litre	l
millilitres	ml
tonne	t
degrees celsius	C^o
bulk density	bd
basic density	sg
oven-dry weight	od wt
diameter at breast height (1.3 m)	dbh
diameter at breast height, squared	d^2
height	h
diameter	dia
diameter at breast height over bark	dbhob
diameter at breast height under bark	dbhub
diameter under bark	dub
basal area	ba
year	yr
approximate	≃, c.
less than	<
greater than or equal to	⩾
log to base 10	log
log to base e	ln
species singular	sp.
species plural	spp.
Queensland Forestry Department	QFD
kilopascal	kPa

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ACKNOWLEDGEMENTS	iv
UNITS OF MEASUREMENT AND ABBREVIATIONS USED	vi
TABLE OF CONTENTS	vii
LIST OF FIGURES	xi
LIST OF TABLES	xiii
LIST OF PLATES	xv
LIST OF APPENDICES	xvi
CHAPTER 1	1
INTRODUCTION	
CHAPTER 2	7
REVIEW OF LITERATURE	
2.1 BIOMASS OF FOREST TREES	7
2.1.1 Stems	7
2.1.2 Branches	9
2.1.3 Foliage	10
2.1.4 Roots	12
2.1.5 Total Tree	15
2.2 BIOMASS OF FOREST STANDS	16
2.2.1 Introduction	16
2.2.2 Multi-Stage Sampling	17
2.2.3 Mean Tree Method	18
2.2.4 Ratio Method	20
2.2.5 Harvest Method	20
2.2.6 Regression Analysis	21
2.2.7 Roots and Dead Organic Matter	23

		Page
2.3	SAMPLING STATISTICS FOR REGRESSION ANALYSIS	27
	2.3.1 Plot Statistics	27
	2.3.2 Sample Trees and Size of Sample	28
	2.3.3 Selection of Independent Variable	31
	2.3.4 Transformation of the Data	33
	2.3.5 Standard Error of Biomass Estimates	35
	2.3.6 Regression — How Good an Estimate	37
CHAPTER 3		39
	STUDY AREA	
3.1	FRASER ISLAND	39
	3.1.1 Location	39
	3.1.2 Climate	39
	3.1.3 Geology and Geomorphology	39
	3.1.4 Physiography	42
	3.1.5 Soils	44
	3.1.6 Vegetation	44
3.2	STUDY SITES	47
	3.2.1 Introduction	47
	3.2.2 Wabby Site	49
	3.2.3 McKenzie Site	49
	3.2.4 Deep Site	51
CHAPTER 4		55
	MATERIALS AND METHODS	
4.1	DESIGN AND LAYOUT	55
4.2	MENSURATION AND STAND TABLE DEVELOPMENT	61
	4.2.1 Large Tree Enumeration	61
	4.2.2 Small Tree Enumeration	66
	4.2.3 Understorey Enumeration	66

Page

4.3 BIOMASS SAMPLING 66

4.3.1 Introduction 66
4.3.2 Litter 68
4.3.3 Understorey 70
4.3.4 Small Trees 74
4.3.5 Medium Roots and Dead Organic Matter 77
4.3.6 Fine Roots 81
4.3.7 Dead Organic Matter Separation 81
4.3.8 Large Trees — Information on Sample Trees 82
4.3.9 Large Tree Sampling on Wabby and McKenzie Sites 85
4.3.10 Large Tree Sampling on Deep Site. 96

CHAPTER 5 106

RESULTS

5.1 REGRESSION EQUATIONS FOR LARGE TREES 106

5.1.1 Blackbutt — Wabby and McKenzie Sites 106
5.1.2 Bloodwood — Wabby Site 113
5.1.3 Bloodwood vs. Blackbutt 113
5.1.4 Blackbutt — Deep Site 115
5.1.5 Non Eucalypt Species — Wabby and McKenzie Sites 123
5.1.6 Regression Equations used to Estimate the Biomass 127

5.2 BIOMASS OF LARGE TREES 127

5.2.1 Wabby Site 133
5.2.2 McKenzie Site 136
5.2.3 Deep Site 139

5.3 BIOMASS OF SMALL TREES 140

5.4 BIOMASS OF UNDERSTOREY 146

5.5 BIOMASS OF SURFACE LITTER 147

5.6 BELOW GROUND BIOMASS 147

5.6.1 Roots 147
5.6.2 Dead Organic Matter 147

Page

CHAPTER 6 154

DISCUSSION

6.1 LARGE TREES — COMPONENT DIFFERENCES BETWEEN SITES 154

6.2 ROOTS 160

6.2.1 Large Roots 160

6.2.2 Fine and Medium Roots and Dead Organic Matter 162

6.3 SMALL TREES 167

6.4 UNDERSTOREY 169

6.5 TOTAL LITTER 171

6.6 TOTAL FOREST 174

CHAPTER 7 180

MANAGEMENT IMPLICATIONS AND CONCLUSION

7.1 MANAGEMENT IMPLICATIONS 180

7.2 CONCLUSION 184

REFERENCES 188

APPENDICES 204

LIST OF FIGURES

		Page
Figure 3.1	Location map of Fraser Island.	40
3.2	Map showing location of place names on Fraser Island and sand dunes on which study sites are located.	41
3.3	Map showing location of study sites.	45
4.1	Location and layout of the study plots and the numbering system adopted for them.	60
4.2	Distribution of the sizes of the large trees on the Wabby site.	62
4.3	Distribution of the sizes of the large trees on the McKenzie site.	63
4.4	Distribution of the sizes of the large trees on Deep site.	64
4.5	Distribution of the sizes of the large trees combined on each of the three sites.	65
4.6	Layout of nested quadrats.	67
4.7	Species - Area curves for the understorey on the Wabby, McKenzie and Deep sites.	72
4.8	Species - Area curves for the small trees on the Wabby, McKenzie and Deep sites.	75
4.9	Distribution Class - Area curves for the large trees on Wabby, McKenzie and Deep sites.	83
4.10	Large roots of the three blackbutt (*Eucalyptus pilularis*) trees sampled on the Wabby site.	94
4.11	Large roots of the four blackbutt (*Eucalyptus pilularis*) trees sampled on the McKenzie site.	95
4.12	Canopy of Tree 500.	99
4.13	Log-log regression equation of sapwood percentage and diameter under bark for structural branches on Tree 500.	100
4.14	Large roots of Tree 500 showing tap-root and the position of the eight major lateral roots.	103
5.1	Regression equations of the log stub diameter and log weight for the blackbutt canopy on the three sites.	110

		Page
Figure 5.2	Foliage and live branch regression equations for blackbutt on Wabby and McKenzie sites with the plotted component weights from Tree 500.	116
5.3	Above ground weight regression equations for blackbutt on Wabby and McKenzie sites and a combination of both along with the weight of Tree 500.	117
5.4	Root weight regression equations for blackbutt on Wabby and McKenzie sites and a combination of both along with the weight of Tree 500.	118
5.5	Total tree weight regression equations for blackbutt on Wabby and McKenzie sites and a combination of both along with the weight of Tree 500.	119
5.6	Combined regression equation from the three sites for the above ground weight.	120
5.7	Combined regression equation from the three sites for the root weight.	121
5.8	Combined regression equation from the three sites for the total weight.	122
5.9	Foliage and branch regression equations and 95% confidence limits for the Wabby site.	124
5.10	Stem regression equations and 95% confidence limits for the Wabby and McKenzie sites.	125
5.11	Distribution of biomass of the fine and medium roots on the Wabby site.	149
5.12	Distribution of biomass of the fine and medium roots on the McKenzie site.	150
5.13	Distribution of biomass of the fine and medium roots on the Deep site.	151
5.14	Distribution of biomass of the components on the three sites.	152
5.15	Distribution of biomass contributed by the forest fractions on the three sites.	153

LIST OF TABLES

		Page
Table 3.1	Approximate ages of dune and beach sands on Fraser Island.	43
4.1	Stand characteristics of the Wabby, McKenzie and Deep sites.	61
4.2	Optimum quadrat size — 90% of Understorey Species.	73
4.3	Optimum quadrat size — 90% of Small Tree Species.	76
4.4	Analysis of Variance. Bark densities for blackbutt on the Wabby site; 7 trees x 5 heights.	89
4.5	Analysis of Variance. Bark densities for blackbutt on the McKenzie site; 6 trees x 9 heights.	89
4.6	Analysis of Variance. Bark densities for blackbutt on the Wabby and McKenzie sites combined; 7 trees x 5 heights.	90
4.7	Analysis of Variance. Sapwood/heartwood densities for blackbutt on the Wabby site; 4 trees x 6 heights x 2 positions.	91
4.8	Analysis of Variance. Sapwood/heartwood densities for blackbutt on the McKenzie site; 6 trees x 9 heights x 2 positions.	92
4.9	Analysis of Variance. Sapwood/heartwood densities for blackbutt on Wabby and McKenzie sites combined; 2 sites x 7 trees x 5 heights x 2 positions.	92
4.10	Structural, supportive and canopy branch weight on Tree 500.	102
4.11	Volume and biomass of large roots from Tree 500.	105
5.1	Regression equations for component weights of *Eucalyptus pilularis* on the Wabby and McKenzie sites.	107
5.2	Regression equations relating the biomass of the canopy components to the diameter of the stub of the supportive branches.	111
5.3	Regression equations used to calculate the biomass of the components of *Eucalyptus intermedia* on the Wabby site.	114
5.4	Regression equations used to calculate the biomass of the components of the large trees on the Wabby site.	128

Page

Table 5.5 Regression equations used to calculate the biomass of the components of the large trees on the McKenzie site. 130

5.6 Regression equations used to calculate the biomass of the components of the large trees on the Deep site. 132

5.7 Biomass (kg ha^{-1}) and standard errors (in parentheses) of the components of the large trees on the Wabby site. 135

5.8 Biomass (kg ha^{-1}) and standard errors (in parentheses) of the components of the large trees on the McKenzie site. 138

5.9 Biomass (kg ha^{-1}) and standard errors (in parentheses) of the components of the large trees on the Deep site. 141

5.10 Biomass (kg ha^{-1}), and standard errors (in parentheses) of the components of small trees, understorey, litter and below ground material on the Wabby site. 142

5.11 Biomass (kg ha^{-1}) and standard errors (in parentheses) of the components of small trees, understorey, litter and below ground material on the McKenzie site. 143

5.12 Biomass (kg ha^{-1}) and standard errors (in parentheses) of the components of small trees, understorey, litter and below ground material on the Deep site. 144

6.1 Biomass (kg ha^{-1}) and standard errors (in parentheses) of the forest fractions on Wabby, McKenzie and Deep sites. 155

6.2 Stem component weights of *Eucalyptus pilularis* on the three sites, expressed as percentages (%). 158

6.3 Biomass of large roots on Wabby, McKenzie and Deep and the proportion of the total biomass contributed by the roots. 161

6.4 Total biomass (t ha^{-1}) of the above and below ground components in eucalypt forests in Australia. 175

6.5 Total biomass (t ha^{-1}) of the above and below ground components in semi arid woodlands in Australia. 176

6.6 Above and below ground biomass (t ha^{-1}) of forest ecosystems in the world. 178

7.1 Standard errors (%) of the estimates of biomass of forest fractions on the Wabby, McKenzie and Deep sites. 186

LIST OF PLATES

		Page
Plate 3.1	Wabby site.	50
3.2	McKenzie site.	52
3.3	Deep site	54
4.1	Root sampling device attached to the tripod, showing Porta-Power in position.	78
4.2	Sampling device removed from the trench and showing the top 5 cm of soil ready for bagging.	78
4.3	Sieving apparatus used to remove sand from roots and dead organic matter.	80
4.4	A typical *Eucalyptus pilularis* tree found on the Deep site.	86
4.5	Tree 500.	87

LIST OF APPENDICES

		Page
Appendix A	Some Plant Species Recorded on Fraser Island	204
B	Physiographic Units on Fraser Island.	224
C	Stratigraphic Sequences of the High Dunes on Fraser Island.	225
D	Growth Stages of Eucalypts on the Three Sites (extract from Jacobs 1955).	226
E	Check List of Species on the Wabby Site.	229
F	Soil Profile Details for the Wabby, McKenzie and Deep Sites.	230
G	Check List of Species on the McKenzie Site.	233
H	Check List of Species on the Deep Site.	234
I	Measurement of Tree Diameter.	236
J	Measurement of Tree Height.	237
K	Method Used for Loss on Ignition Tests to Determine Sand Percentage.	238