

THE NATURE OF SOILS UNDER
BLACKBUTT AND FLOODED GUM FOREST
COMMUNITIES NEAR COFFS HARBOUR, N.S.W.

by
Philip Joseph Ryan

A thesis submitted in
fulfilment of the requirements
for the degree of Master of Natural
Resources, University of New England
August, 1979.

ACKNOWLEDGEMENTS.

I wish to express my appreciation to my supervisor Professor J. W. McGarity, Department of Agronomy and Soil Science, University of New England for his supervision and constructive criticism of the manuscript, and to the academic and technical staff of the Department of Ecosystem Management, especially Professor B.N. Richards and Mr. J. A. Duggin who have aided and advised me innumerable times.

Special thanks go to the Forest Commission of N.S.W. and especially the officers of the Coffs Harbour District whose advice and assistance allowed me to select the study sites in the State Forests of the Coffs Harbour Region.

Many other individuals, both inside and outside the University, have contributed to this study by assisting me with field work, laboratory analysis, statistical procedures and proof-reading the manuscript. To all these people I wish to express my thanks and gratitude.

Finally, I would like to gratefully acknowledge the fine typing and layout of Mrs. Lorraine Stephens, and Mrs. Jan Skuthorpe.

SUMMARY

The nature of the forest soils under a lower slope, wet sclerophyll, flooded gum (Eucalyptus grandis) forest community and an upper slope, dry sclerophyll, blackbutt (E. pilularis) forest community was studied near Coffs Harbour, New South Wales. The relationship of changes in the spatial distribution of the soil properties beneath a large flooded gum and two large blackbutt trees were analysed to determine what properties of the soil were dependent upon the influence of the forest vegetation, especially the presence of the individual trees and how variable were the distribution of these properties.

14 soil profiles were described and their mineralogical, morphological, physical and chemical properties characterized from pits excavated radial to the boles of the large blackbutt and flooded gum trees. Differences in the morphological soil horizons of the pit sections were recorded graphically by visual and photographic observations. Additional data were obtained from soil cores sampled on a grid pattern over the faces of the pits and forest litter transects radial to the eucalypt boles.

The soil adjacent to both the eucalypts had higher exchangeable Al, soil organic carbon, cation exchange capacity and lower pH than the soil away from the boles, towards the canopy edge. The flooded gum site had higher bulk density in the B horizon adjacent to the tree and these areas of high bulk density, exchangeable Al, and low pH persisted in the soil after the tree had died and/or had been wind thrown. The blackbutt soils had a greater variance in the values of base saturation, pH and exchangeable Al, between soils next to and away from the boles than that found at the flooded gum site. Total soil N, and P increased while C:N ratios decreased from the blackbutt to the flooded gum site.

The O and A horizons were thicker, more differentiated, and the B horizons were mottled, with some gleying, towards the flooded gum. The blackbutt soils were variable next to the boles with numerous discontinuous horizons and abundant large roots disrupting the profile morphology. Small areas of mottled

B horizon were found in subsoil adjacent to the root-stock and in general the B or C horizon were more developed next to the boles. Away from the blackbutt boles the solums were shallower and the A horizons thicker.

Three soil classification systems (Northcote's Key, Great Soil Groups of Australia and Soil Taxonomy) were assessed as to their capability to recognise and utilize the significant soil properties and soil forming processes that were a result of or influenced by the presence of the forest communities.

The spatial variation of soil properties about the large eucalypts were interpreted as indicating the effect of the forest trees in influencing the distribution and impact of forest pedogenetic factors such as organic matter, tree roots and forest organisms, about their boles. Concentrations of stemflow water, differential litter accumulation, root pedoturbation and the mechanical pressures of the tree combined to produce one form of soil morphology associated with the tree boles while increased pedoturbation by soil fauna, especially earthworms, (flooded gum site) or the shallowness of the solum (blackbutt site) produced a differing soil morphology away from the eucalypts.

Therefore this study provides evidence for the hypothesis that the individual trees of different forest communities can induce spatial heterogeneity in soil chemical, physical and morphological properties, and that the nature of these patterns are dependent upon features of the soil landscape (depth of solum, soil texture etc.) and the particular nature of the tree species. This latter factor causes the spatial soil patterning to be dynamic and stochastic in its development.

TABLE OF CONTENTS

	Page
PREFACE	 ii
ACKNOWLEDGEMENTS	 iii
SUMMARY	 iv
TABLE OF CONTENTS	 vi
LIST OF TABLES	 xi
LIST OF FIGURES	 xii
LIST OF PLATES	 xiv
<u>CHAPTER ONE. THE PROPERTIES AND CLASSIFICATION OF FOREST SOILS</u>	1
I. INTRODUCTION	1
II INTERRELATIONSHIPS BETWEEN FOREST AND SOIL: A REVIEW OF THE LITERATURE	3
1.1 THEORETICAL BACKGROUND	3
(a) <u>Theories of Soil Formation and the Role of Vegetation</u>	3
(b) <u>Application of Theoretical Concepts</u>	7
(1) Edaphic delimitation of plant communities; vegetation as the dependent variable:	8
1.2 THE INFLUENCE OF FOREST VEGETATION ON SOIL DEVELOPMENT	10
(a) <u>Forest Pedogenetic Factors:</u> <u>I. Organic Matter and Forest Floor</u>	10
(b) <u>Forest Pedogenetic Factors: II. Tree Roots</u>	13
(c) <u>Forest Pedogenetic Factors:</u> <u>III. Specific Organisms</u>	15
(d) <u>Forest Pedogenetic Factors: IV. The Tree</u>	16
(1) The Tree: direct effects:	17
(2) The Tree: indirect effects:	17
(3) Stemflow:	19
1.3 CLASSIFICATION OF FOREST SOILS	27
(a) <u>Major Soil Groups under Forest</u>	27
(1) The morphology and classification of brown forest soils:	28
(b) <u>Separation Classification of Forest Soils</u>	30
(1) Europe and Russia:	30
(2) U.S.A.:	30
(3) Australia:	31
(c) <u>Conclusions</u>	32
<u>CHAPTER TWO. DESCRIPTION OF THE STUDY AREA AND THE METHODS OF INVESTIGATION</u>	33
(a) <u>Introduction</u>	33

	Page
2.1 DESCRIPTION OF THE STUDY AREA	33
(a) <u>Location</u>	33
(b) <u>Topography and Geography</u>	33
(c) <u>Geology</u>	35
(d) <u>Climate</u>	37
(e) <u>Vegetation</u>	40
(f) <u>The Autecology of Blackbutt:</u> <u>Eucalyptus pilularis</u>	40
(1) Reproductive physiology:	42
(2) Habitat relationships:	42
(3) Edaphic interactions:	42
(g) <u>The Autecology of Flooded Gum:</u> <u>Eucalyptus grandis</u>	45
(1) Reproductive physiology:	45
(2) Habitat relationships:	46
(3) Edaphic interactions:	46
(4) Other factors:	46
(h) <u>The Soil Resource</u>	47
(1) A review of past soil investigations and surveys:	47
2.2 METHODS OF INVESTIGATION	49
(a) <u>Field Procedures</u>	49
(1) Selection of study sites:	49
(2) Bruxner Park site:	50
(3) McNamaras Road site:	53
(b) <u>Description and Sampling of Soil Profiles</u>	57
(1) Description of soil profiles:	57
(2) Sampling procedures:	57
(c) <u>Spatial Patterning in Soil Pit Sections</u>	58
(d) <u>Laboratory Procedures</u>	62
(1) Sample preparation:	62
(2) Moisture content:	62
(3) Particle size analysis:	62
(4) Bulk density:	62
(5) pH:	63
(6) Exchangeable bases and cation exchange capacity:	63
(7) Exchangeable acidity:	63
(8) Base saturation:	63
(9) Organic carbon:	64
(10) Total nitrogen:	64
(11) Total phosphorus:	64
(12) Extractable iron oxides:	64
(13) Xray diffraction of clay samples	64
<u>CHAPTER THREE. MORPHOLOGY AND CLASSIFICATION OF THE FOREST SOILS AND THE SPATIAL PATTERNING OF THEIR PROPERTIES</u>	66
3.1 INTRODUCTION	
(a) <u>Procedures for Describing the Soil Profiles</u>	66
(1) Profiles adjacent to the eucalypts:	67

	Page
(b) <u>Procedures for Classification of the Soil Profiles</u>	67
(c) <u>Procedures for Characterizing Soil Spatial Heterogeneity</u>	68
3.2 <u>SPATIAL PATTERNING OF SOIL CHEMICAL AND PHYSICAL PROPERTIES</u>	68
(a) <u>Pit C - Bruxner Park Site</u>	69
(1) Bulk Density (Figure 3.1c):	73
(2) Field moisture content (Figures 3.1b and 3.3b):	73
(3) pH (Figures 3.2a, 3.2b and 3.3a)	73
(4) Soil Organic Matter:	74
(b) <u>Pit A - Bruxner Park Site</u>	74
(1) Bulk density (Figure 3.5b):	74
(2) Field moisture content (Figures 3.6a and 3.6b):	74
(3) pH (Figure 3.5a):	78
(c) <u>Pit E - McNamaras Road Site</u>	78
(1) pH (Figures 3.8a, 3.8b, 3.9a):	82
(2) Gravimetric field moisture content (Figure 3.9b):	82
(d) <u>Correlation Between Soil Grid-Point Data</u>	82
3.3 <u>THE SOIL PIT PHOTOMOSAICS</u>	83
3.4 <u>MORPHOLOGY OF THE FOREST SOILS</u>	90
(a) <u>General Morphology</u>	91
(1) The Bruxner site profiles:	91
(2) The McNamaras site profiles:	91
(b) <u>Bruxner Park Profile Morphology</u>	92
(1) O horizons:	92
(2) A horizons:	92
(3) B1 horizons:	92
(4) B2 horizons:	93
(5) B31 horizons:	93
(6) B32 horizons:	93
(c) <u>Spatial Variability of the Bruxner Park Site Soil Morphology</u>	93
(1) Soil morphological features associated with the flooded gum:	93
(2) Morphology of the windthrow pit soil - Profile 2A:	95
(3) Profile 1D:	97
(d) <u>McNamaras Road Profile Morphology</u>	98
(1) Shallow brown soils away from the blackbutts:	98
(2) Brown soils of complex morphology adjacent to the blackbutts:	101
(3) Shallow lithosols adjacent to the blackbutts:	106
(e) <u>Selected Horizon Morphology of the McNamaras Road Site</u>	107
(1) The A3* horizon:	107
(2) The B23* horizon:	107

	Page
(f) <u>Spatial Patterning of the McNamaras Road Site Morphology</u>	107
(1) Pit E - Figure 3.7:	109
(2) Pit F - Figure 3.10:	109
(3) Pit G - Figure 3.11:	111
(g) <u>Spatial Distribution of Surface Organic Horizons</u>	111
(h) <u>Other Morphological Features</u>	114
(1) Earthworm casts - Bruxner Park site:	114
(2) Soil concretions - Bruxner Park site:	118
(3) Soil concretions - McNamaras Road site:	120
(4) Pale soil aureoles around roots:	120
3.5 <u>CLASSIFICATION OF FOREST SOILS</u>	121
(a) <u>Forest Humus Types</u>	121
(b) <u>Classification of the Bruxner Park Profiles</u>	121
(1) Great Soil Groups:	125
(2) Northcote Factual Key:	125
(3) Soil Taxonomy:	125
(c) <u>Classification of the McNamaras Road Profiles</u>	126
(1) Great Soil Groups:	126
(2) Northcote Factual Key:	126
(3) Soil Taxonomy:	126
(d) <u>General Comments</u>	128
<u>CHAPTER FOUR. THE CHEMICAL, PHYSICAL AND MINERALOGICAL PROPERTIES OF THE FOREST SOILS</u>	130
(a) <u>Introduction</u>	130
4.1 <u>SOIL MINERALOGY</u>	130
(a) <u>Parent Materials</u>	130
(b) <u>Clay Mineralogy</u>	133
(1) Bruxner Park site clays:	133
(2) McNamaras Road site clays:	135
4.2 <u>PHYSICAL PROPERTIES</u>	137
(a) <u>Mechanical Analysis</u>	137
(b) <u>Bulk Density</u>	140
4.3 <u>CHEMICAL PROPERTIES</u>	143
(a) <u>Soil Organic Carbon</u>	143
(b) <u>The Exchange Complex</u>	143
(1) Cation exchange capacity:	148
(2) The exchangeable bases:	148
(3) Exchangeable acidity:	150
(4) Base saturation:	150
(c) <u>Total Soil Nitrogen and Phosphorus</u>	153
(d) <u>pH</u>	156
4.4 <u>STATISTICAL ANALYSIS OF SOIL PROFILE DATA</u>	159
(a) <u>Analysis of Variance: The Bruxner Park Profiles</u>	159
(1) Results and Discussion:	159

	Page
(b) <u>The Contribution of Soil Organic Matter and Clay Content to the Cation Exchange Capacity of the Forest Soils</u>	163
(1) Regression analysis:	163
<u>CHAPTER FIVE. GENESIS OF THE BLACKBUTT AND FLOODED GUM SOILS</u>	168
5.1 THE EFFECT OF RELIEF AS A SOIL FORMING FACTOR	168
(a) <u>Polygenesis of the Bruxner Park Site Soils</u>	169
(1) Profile 1D:	172
5.2 SOIL FORMATION NEAR LARGE BLACKBUTT AND FLOODED GUM	173
(a) <u>Soil Properties Influenced by the Eucalypts</u>	173
(1) Flooded gum:	173
(2) Blackbutt:	174
(b) <u>Factors Influencing the Soil Adjacent to the Eucalypts</u>	175
(1) Stemflow:	175
(2) Organic matter and forest floors:	176
(3) Tree roots:	177
(4) Forest soil organisms:	178
(5) The tree:	179
(c) <u>Conclusions</u>	180
5.3 GENERAL DISCUSSION AND CONCLUSIONS	182
(a) <u>Implications to Classification of Forest Soils</u>	184
(b) <u>Implications to Forest Managements</u>	185
BIBLIOGRAPHY	186
APPENDIX I	201
APPENDIX II	202
APPENDIX III	204
APPENDIX IV	242
APPENDIX V	244
APPENDIX VI	247
APPENDIX VII	249
APPENDIX VIII	253

LIST OF TABLES

- 1.1 A Summary of data regarding the spatial patterning of soil properties about individual trees.
- 2.1 Climatic data for the Coffs Harbour Region.
- 3.1 Correlation coefficients (r) for pairs of soil parameters from grid sampling Pits C, A; Bruxner Park Site and Pit E; McNamaras Road Site.
- 3.2 Comparative soil morphological properties for profiles 3A and 1C, Bruxner Park Site.
- 3.3 The Morphology of the Shallow Brown Soils away from the Blackbutts.
- 3.4 The morphology of the profiles adjacent to the Blackbutts.
- 3.5 Comparison of earthworm cast material (EC) to corresponding profile horizon data (from Appendix III) for profiles 3A and 1A.
- 3.6 Classification of forest humus types after Hoover and Lunt (1952).
- 3.7 Classification of the Bruxner Park Site Profiles.
- 3.8 Classification of the McNamaras Road Site Profiles.
- 4.1 Modal analysis of greywackes from Units A and B, Coramba Beds, Coffs Harbour.
- 4.2 Total chemical analysis of the parent materials of profiles 2F and 2G, McNamaras Road Site.
- 4.3 Exchange complex data for 2 representative profiles from the Bruxner Park site.
- 4.4 Exchange complex data for 2 representative profiles from McNamaras Road site.
- 4.5 C:N Ratios for the A and B horizons of the flooded gum (BP) and blackbutt (MR) sites. Mean values $\pm$ standard deviations with the number of samples in parentheses.
- 4.6 A summary of the AOV tables (Appendix VII) for the 3 profile group comparison and the main effects of the Profile Groups.
- 4.7 Single and multiple regression equations relating CEC to soil organic carbon (%C) and/or percentage clay (CL) of the forest soil profiles.

LIST OF FIGURES

- 1.1 Lateral variation in net precipitation and forest litter inputs as influenced by a large tree.
- 1.2 A schematic, vertical flow diagram of rainfall portioning in a forest.
- 2.1 Map of the Coffs Harbour region showing areas of State Forest.
- 2.2 Geology of the Coffs Harbour Region: the Coramba Beds (units A, B, C and D) and the Brooklana Beds of the Coffs Harbour Block, the Clarence-Moreton Basin to the north and recent alluvial deposits (stippled area). Redrawn from Korsch (1978).
- 2.3 Mean Monthly Rainfall data for Coffs Harbour, Lower Bucca, Coramba and Woolgoolga.
- 2.4 The edaphic relationships of blackbutt in northern N.S.W. (adapted from Florence, 1968).
- 2.5 The mapping units of the Atlas of Australian Soils for the Coffs Harbour region. Adapted from Northcote (1966), Sheet 3.
- 2.6 A section of the 1:25,000 showing the topography of the Study Sites.
- 2.7 Plan and diagram of the Bruxner Park site (BP). Litter transects are indicated as dashed lines.
- 2.8 Plan of the excavations at the two blackbutts BB1 and BB2, McNamaras Road site. Litter transects are shown as dotted lines.
- 2.9 A diagram depicting the sequence of procedures used in constructing a photomosaic map and a graphical drawing of horizon boundaries of a soil pit face. Refer to text explanation.
- 3.1 Pit C soil morphology and isograms.
- 3.2 Pit C isograms.
- 3.3 Pit C isograms.
- 3.4 Soil morphology showing boundaries of horizons.
- 3.5 Pit A Isograms.
- 3.6 Pit A Isograms.
- 3.7 Soil morphology of Pit E showing boundaries of horizons.
- 3.8 Pit E Isograms.
- 3.9 Pit E Isograms.
- 3.10 Soil morphology showing boundaries of horizons.
- 3.11 A exploded graphical view of the soil morphology of part of Pit G.
- 3.12 The relationship between organic horizon component weights and the distance from the eucalypt boles.

- 3.13 Properties of soil aureoles adjacent to major roots near eucalypt boles.
- 4.1 Xray diffractogram for clay samples of selected horizons of profiles 2C and 1C; Bruxner Park Site.
- 4.2 Xray diffractograms for clay samples of selected horizons of profiles 2E, 1E and 2G; McNamaras Road Site.
- 4.3 Percent clay and silt + clay as functions of soil depth for the Bruxner Park site profiles.
- 4.4 Percentage clay and silt + clay as functions of soil depth for the McNamaras Road site.
- 4.5 Bulk density as a function of soil profile depth for the McNamaras Road site data.
- 4.6 Bulk density as a function of soil profile depth for the Bruxner Park site data.
- 4.7 Percentage soil organic carbon as a function of soil depth for all the Bruxner Park site profiles.
- 4.8 Percentage soil organic carbon and CEC as functions of soil depth for the McNamaras Road site profiles.
- 4.9 CEC as a function of soil depth for all the Bruxner Park Site profiles.
- 4.10 Percentage exchangeable aluminium (Al) as a function of soil depth for both Bruxner Park and McNamaras Road profile data.
- 4.11 Percentage base saturation as functions of soil depth for the Bruxner Park profile data (a) and the McNamaras Road Site profile data (b).
- 4.12 Total soil phosphorus (top) and soil nitrogen (bottom) as functions of soil profile depth for the Bruxner Park site data (individual profile markers) and the McNamaras Road site data.
- 4.13 $\text{pH}(\text{H}_2\text{O})$ and the $\text{pH}(\text{KCl})$ as functions of soil profile depth for the McNamaras Road site data.
- 4.14 $\text{pH}(\text{H}_2\text{O})$ and the $\text{pH}(\text{KCl})$ as functions of soil profile depth for the Bruxner Park site data.
- 4.15 The experimental design for analysis of the Bruxner Park Site profile data.
- 5.1 Possible genetic pathways for the Bruxner Park site soils.
- 5.2 Possible genetic pathways for the McNamaras Road site soils.

LIST OF PLATES

- 2.1 The forest type map of Lower Bucca and Orara East State Forests, north of Coffs Harbour (Cat.No.SF986; SHF.394).
- 2.2 The selected individual eucalypts.
- 2.3 The apparatus used to photograph the pit face with series of overlapping, orthogonal photos from which a photomosaic map of the pit face could be produced. See the text for detailed description.
- 3.1 The Pit C photomosaic.
- 3.2 The Pit A photomosaic.
- 3.3 The Pit B and profiles 1D and 1C photomosaics.
- 3.4 The Pit D and profiles 2D and 1E photomosaics.
- 3.5 Pit G, McNamaras Road site; from base of blackbutt BB1 (left) to profile 3G.
- 3.6 Profile 2G and adjacent soil; McNamaras Road site.
- 3.7 Profile 2F; 5m from blackbutt BB2, McNamaras Road Site.
- 3.8 Profile 1G, adjacent to blackbutt BB1; McNamaras Road site.
- 3.9 Profile 1F, adjacent to blackbutt BB2; McNamaras Road site.
- 3.10 Earthworm casts in the Bruxner Park site soils.
- 3.11
 - a) Coarse sand fractions from the B1 horizon of profiles 1A and 3A (A1.4 and A3.4 respectively); Bruxner Park site, compared with the coarse sand from earthworm casts of the same horizon (A1.4:W1, and A3.4:W5).
 - b) A soil clod from the A1 horizon next to blackbutt BB1, McNamaras Road site.