



UNIVERSITI PUTRA MALAYSIA

**SOIL-LANDSCAPE RELATIONSHIPS IN KEDAH -
A STUDY IN SOIL GENESIS AND CLASSIFICATION**

LIM JIT SAI

FP 1991 3

**SOIL-LANDSCAPE RELATIONSHIPS IN KEDAH -
A STUDY IN SOIL GENESIS AND CLASSIFICATION**

By

LIM JIT SAI

**A Thesis Submitted in Fulfilment of
the Requirements for the Degree of
Doctor of Philosophy In the
Faculty of Agriculture,
Universiti Pertanian Malaysia**

January, 1991



DEDICATION

TO ALL SOIL SURVEYORS



ACKNOWLEDGEMENTS

This study has taken me 7 years, working on a part-time basis, to complete. Its completion would not have been possible if not for the encouragement, moral support, generous cooperation and technical assistance that I have received from my superior officers, academic staff of Universiti Pertanian Malaysia, staff of the Soil Management Branch, colleagues, friends and members of my family. I want to put on record my appreciation the contributions of these wonderful people and many others, who have in one way or another, helped me to finish this study.

I am most thankful to the Director-General of the Department of Agriculture, Malaysia, Dato' Abu Bakar Mahmud, for his constant call and encouragement to officers of the Department of Agriculture to strive for professional excellence. This study represents my efforts towards achieving this goal in my own area of work.

I also wish to thank the former Director and Deputy Director of the Soil Management Branch, Department of Agriculture, Mr. Law Wei Min and Mr. I.F.T. Wong and the present Director and Deputy Director of the Soil Management Branch, Mr. Abdul Jamil Mohd Ali and Dr. Chan Yik Kuan, for their encouragement and support.



I wish to thank Universiti Pertanian Malaysia, especially the Board of Graduate Studies, for giving me the opportunity to enhance my academic knowledge by allowing me to participate in the doctoral programme.

My appreciation also goes to the Head of the Soil Science Department of the Faculty of Agriculture for his full support and making available all the facilities necessary for this study.

Thanks are due the staff of the Soil Management Branch, Telok Chengai, Kedah for their excellent cartographic work and the analysis of the soil samples. The contribution by Mr. Sulaiman Hassan in the drawing of the block diagrams is gratefully acknowledged. The final diagrams and figures are drawn by the capable and versatile cartographic team consisting of Mr. Zahry Abdul Rahman, Mrs Salmah Hussin, Mrs. Norhayati Abdul Rashid and Miss Zaiton Samsu. The results of laboratory routine analyses are the contributions of Mr. Abdul Manan bin Saleh, Mr. Teoh Tee Wong, Mrs. Labibah Hashim, Mrs. Hashimah Hashim, Mr. Murad bin Arshad and Mr. Mohd Akhir Mat. To these wonderful people, I want to say "Terima kasih".

The X-ray diffractograms were completed by the mineralogy laboratories of the Department of Agriculture and the Universiti Pertanian Malaysia. I want to thank Peter Yun for helping me to complete these analyses.



The preparation of the thin sections was completed in the micromorphological laboratory of Universiti Pertanian Malaysia. I want to thank Mr. Azmi who helped me in this aspect of my work.

My friend, Dr. Wong Chaw Bin and my brother, Mr. Lim Boh Ang, helped to proof-read this thesis. I thank them for taking time off from their busy schedules to read the thesis.

My appreciation also goes to Dr. Siti Zauyah Darus, of the Soil Science Department, Universiti Pertanian Malaysia, for her patience and generous help in the micromorphological study. I want to thank her for having patiently updated me on the latest techniques and developments on micromorphology. I am indeed privileged to have received tutoring from the foremost authority on micromorphology in the country. For all her contributions, I want to say, "Terima Kasih, Cikgu".

To my dear wife, Yit Chow Mee, for helping to take care of our home and children, Robin, Justin and Lianne, and for showing extreme patience, love and understanding, I convey my heartfelt thanks and love.

This study would not have been initiated if not for the encouragement and support of one person, whom I know I cannot thank enough with words. He was my first teacher in soil survey, genesis, classification and land evaluation from the very



first day that I started my career in the Department of Agriculture in 1972 and has since continued to inspire me to strive for professional excellence. As the Head of the Soil Survey Section, he not only guided and taught me but he also worked with me, which was his special way of giving his personal attention to the officers under his supervision. When he was appointed Associate Professor in the Soil Science Department of the Faculty of Agriculture, Universiti Pertanian Malaysia, he encouraged me to improve my career professionally through academic studies. It was due mainly to his encouragement, support, guidance, patience, understanding and constant supervision and help that I have now completed this study. To you, Dr. S. Paramanathan, I thank you for everything from the bottom of my heart. Had it not been for you, I would not have come this far.

To many others whose names are not mentioned here, I want to assure you that I appreciate your help and support.

Last but not least, I thank God for sustaining and upholding me throughout the duration of this study. Without His Almighty support, it would not have been possible for me to carry out my full time job effectively while at the same time undertake this study on a part-time basis. But with God, all things are possible.



TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iii
LIST OF TABLES	xviii
LIST OF FIGURES	xxi
LIST OF PLATES	xxv
ABSTRACT	xxix
ABSTRAK	xxxii
 CHAPTER	
1. INTRODUCTION	1
General Background	1
Objectives of Study	2
2. REVIEW OF LITERATURE	4
Geology of Kedah	4
Physiography and Drainage	11
Landscape Evolution	16



Beach Ridges Interspersed with Swales (BRIS)	16
Muda Coastal Plain	18
Pediaplains and Peneplain Surfaces (P, P3, P2)	18
Soil Survey in Kedah	33
Soil Genesis	36
Soils on Beach Ridges and Sandy Materials	36
Muda Marine Coastal Plain	43
Pediplain Soils	48
Need for this Study	50
3. MATERIALS AND METHODS	52
Location	52
Climate	52
Selection of Landscapes and Soils	61
Langkawi Island	62
Mainland Kedah	63
Soil Sampling and Preparation	65
Methods of Analysis	66
Granulometry	66
Chemical Analyses	66

Mineralogical Analysis	71
Micromorphological Study	72
4. RESULTS AND DISCUSSIONS	74
I. SOILS DEVELOPED ON BEACH RIDGES ON LANGKAWI ISLAND	74
The BRIS landscapes in Padang Matsirat, Pulau Langkawi	74
Description of Soils of Baging Series (Plate 1)	78
Morphological Characteristics	78
Particle-Size Distribution	80
Chemical Properties	81
Mineralogical Properties	83
Micromorphology	83
Rudua Series (W1) and Rudua Series (W2)	86
Description of Rudua Series (W1) (Plate 3)	88
Morphological Characteristics	88
Particle-Size Distribution	91
Chemical Properties	92
Mineralogical Properties	94
Micromorphology	96
Description of Rudua Series (W2) (Plate 5)	98



Morphological Characteristics	98
Particle-Size Distribution	102
Chemical Properties	103
Mineralogical Properties	105
Micromorphology	105
Description of Rudua Series (H) (Plate 7)	109
Morphological Characteristics	109
Particle-Size Distribution	111
Chemical Properties	112
Mineralogical Properties	115
Micromorphology	115
Description of Pauh Series (Plate 9)	118
Morphological Characteristics	118
Particle-Size Distribution	121
Chemical Properties	122
Mineralogy	125
Micromorphology	125
Soil Classification	127
Soil Genesis on Sandy Beach Ridges	131
Evolution of the Beach Ridges	139
Soil Formation	133



II. SOILS DEVELOPED ON MUDA MARINE COASTAL PLAINS OF KEDAH	148
Physiography and Formation of the Muda Plain	148
Description of the Serong Series, moderately deep phase (Plate 12)	150
Morphological Characteristics	150
Particle-Size Distribution	154
Chemical Properties	155
Mineralogical Properties	160
Micromorphology	160
Description of Sedaka Series (Plate 16)	166
Morphological Characteristics	166
Particle-Size Distribution	169
Chemical Properties	170
Mineralogical Properties	173
Micromorphology	174
Description of the Chengai Series (Plate 19)	178
Morphological Characteristics	178
Particle-Size Distribution	184
Chemical Properties	185
Mineralogical Properties	188
Micromorphology	190
Description of the Hutan Series (Plate 25)	192



Morphological Characteristics	192
Particle-Size Distribution	195
Chemical Properties	196
Mineralogy	198
Micromorphology	200
Soil Classification	202
Soil Formation on the Muda Plain	207
Soil Catena	207
Factors of Soil Formation	213
Morphological Properties	213
Physico-Chemical Properties	230
Mineralogy	230
III. SOILS ON PEDIPLAINS AND PENEPLAIN SURFACES (P, P3 AND P2) IN KEDAH	258
Introduction	258
Definitions	259
Description of Malacca Series (Plate 29)	262
Morphological Characteristics	262
Particle-Size Distribution	265
Chemical Properties	267
Mineralogy	269



Micromorphology	269
Description of the Gajah Mati Series (Plate 31)	273
Morphological Characteristics	273
Particle-Size Distribution	273
Chemical Properties	273
Mineralogy	278
Micromorphology	278
Description of the Prang Series (Plate 34)	283
Morphological Characteristics	283
Particle-Size Distribution	285
Chemical Properties	286
Mineralogy	287
Micromorphology	288
Lateritic and Non-Lateritic Soils in Northern Kedah	291
Description of the Pokok Sena Series (Plate 36)	291
Morphological Characteristics	291
Particle-Size Distribution	294
Chemical Properties	295
Mineralogy	299
Micromorphology	299

Description of Serdang Series (Plate 39)	306
Morphological Characteristics	306
Particle-Size Distribution	309
Chemical Properties	309
Mineralogy	311
Micromorphology	311
Soil Classification	314
Application of the Concepts of P, P3 and P2 Surfaces and Pediments and their Soils in Kedah	317
Landscapes	317
Soils	324
Identification of Lateritic Soils	336
Criteria to Differentiate P, P3 and P2 Surfaces	338
Table to the Identification of Lateritic Soils	338
Testing of the Table to the Identification of Lateritic Soils	346
5. GENERAL DISCUSSION	347
Introduction	347
Soil-Landscape Relationship	351
Soil Properties	352
Morphological Characteristics	352



Chemical Properties	358
Mineralogy	365
Micromorphology	365
Soil Classification	367
6. SUMMARY AND CONCLUSIONS	369
Purpose of Study	369
Major Landscapes and Soils	369
BRIS Soils	370
Soils of Muda Plain	371
Pediplain Soils	373
BIBLIOGRAPHY	374
 APPENDICES	
APPENDIX A - Baging Series	385
APPENDIX B - Rudua Series (W1)	389
APPENDIX C - Rudua Series (W2)	394
APPENDIX D - Rudua Series (H)	399
APPENDIX E - Pauh Series	403
APPENDIX F - Serong Series, moderately deep phase	407



APPENDIX G - Sedaka Series	.....	411
APPENDIX H - Chengai Series	.....	415
APPENDIX I - Hutan Series	.....	419
APPENDIX J - Malacca Series	.....	424
APPENDIX K - Gajah Mati Series	.....	428
APPENDIX L - Prang Series	.....	432
APPENDIX M - Pokok Sena Series	.....	436
APPENDIX N - Serdang Series	.....	441
APPENDIX O - Horizon Symbols	.....	446
BIOGRAPHICAL SKETCH	.....	447



LIST OF TABLES

Table	Page
1. Geological Succession of Kedah and Perlis	6
2. Organic Matter and Free Iron of Rudua Series (W1), Rudua Series (W2) and Rudua Series (H)	141
3. Clay, Silt and Free Iron Oxide Contents of Soils Developed on Beach Ridges	144
4. Relationship Between CEC/clay Ratio and Clay Mineralogy	159
5. Classification of the Muda Soils	205
6. Distance and Elevation of Muda soils From the Coast	212
7. Profile Development of Muda soils	215
8. Organic Carbon Content of Ap Horizons of Soils of Marine and Riverine Alluvia	225
9. Some Properties of the Plough Soles of Soils on Marine and Riverine Alluvia	229
10. Electrical Conductivity, ESP and pH of Muda soils	245



11.	Table to the Identification of Non-acid Sulphate Marine Clay Soils	253
12.	Mineralogy and CEC of the Muda soils	257
13.	Clay, Silt and Sand Contents treated with 20 ml and 150 ml of Hydrogen Peroxide of Bo2c Horizon of Malacca Series	267
14.	CEC of Clay After Making Adjustments to CEC Due to Organic Matter in the Pokok Series	298
15.	Differences Between the P/P3 Surfaces and the Pediments	323
16.	Some Criteria for the Separation of the Lateritic Peneplain Soils	340
17.	Table to the Identification of Soils with Reworked Lateritic Stonelines	342
18.	Major Properties of Soils of the BRIS, Muda, Pediplain and Residual Landscapes	348
19.	Analytical Data of Baging Series	387
20.	Analytical Data of Rudua Series (W1)	392
21.	Analytical Data of Rudua Series (W2)	397
22.	Analytical Data of Rudua Series (H)	401
23.	Analytical Data of Pauh Series	405
24.	Analytical Data of Serong Series, moderately deep phase	409
25.	Analytical Data of Sedaka Series	413
26.	Analytical Data of Chengai Series	417



27.	Analytical Data of Hutan Series	422
28.	Analytical Data of Malacca Series	426
29.	Analytical Data of Gajah Mati Series	430
30.	Analytical Data of Prang Series	434
31.	Analytical Data of Pokok Sena Series	439
32.	Analytical Data of Serdang Series	444



LIST OF FIGURES

Figure	Page
1. Geology of Kedah and Perlis	5
2. Location of Kedah showing the Muda Plain and the Hinterland	12
3. The Main Physical and Political Features of Kedah	13
4. Major Landscapes in Kedah	15
5. The Distribution of Raised Beaches and Alluvium in the Padang Mat Sirat and Ulu Melaka Areas of Langkawi Island	19
6. The Standard Hillslope of King (1962)	24
7. Characteristics of a Pedisediment Profile (adapted after De Dapper, 1981)	27
8. Slope Pedimentation and Development of Pediments and Pediplains	30
9. Model Indicating the Differentiation of Stoneline, Pediment Gravel and Pediment Wash Below a Retreating Scarp (after Folster, 1981)	32
10. Characteristics of a Pediment Showing the Etchplain and R.O.P. (after De Dapper, 1981)	34
11. Progress of Semi-detailed Soil Survey in Kedah, 1986	37



12.	Location of the State of Kedah within Peninsular Malaysia	53
13.	Map of Kedah Showing Political Boundaries, Communications and Drainage	54
14.	Mean Annual Rainfall of Kedah	58
15.	Water Balance of Alor Setar, Pulau Langkawi and Baling	59
16.	Water Balance of Sungai Petani, Kulim and Bandar Baru	60
17.	Block Diagram of Padang Matsirat Area and Padang Saga, Langkawi Island Showing the Soil and Landscape Relationship	76
18.	West-east Cross-section of Padang Matsirat and Padang Saga, Langkawi Island Showing Soil and Landscape Relationship	77
19.	X-ray Diffractograms of Clay and Silt Fractions of Baging Series	84
20.	X-ray Diffractograms of Clay and Silt Fractions of Rudua Series (W1)	95
21.	X-ray Diffractograms of the Clay and Silt Fractions of Rudua Series (W2)	106
22.	X-ray Diffractograms of the Clay and Silt Fractions of Rudua Series (H)	116
23.	X-ray Diffractograms of Clay and Silt Fractions of Pauh Series	126
24.	Stability Fields Related to Eh and pH (after Collins and Buol, 1969)	146
25.	Major Landforms Found in the Kedah-Perlis Coastal Plain of Peninsular Malaysia and Location of Soil Pits	151



26.	X-ray Diffractograms of the Clay and Silt Fractions of Serong Series	161
27.	X-ray Diffractograms of the Clay and Silt Fractions of Sedaka Series	175
28.	X-ray Diffractograms of the Clay and Silt Fractions of Chengai Series	189
29.	X-ray Diffractograms of the Clay and Silt Fractions of the Hutan Series	199
30.	Block Diagram of the Muda Plain Showing the Main Landforms	208
31.	Fluctuation of the Ground Water Table at Telok Chengai	210
32.	Cross-section of the Muda plain Showing Major Landscapes and Soils	211
33.	Changes in pH with Distance From the Sea	234
34.	Changes in EC with Distance From the Sea	235
35.	Distribution of Cations of the Top 10 cm as a Function of Distance From the Coast	237
36.	Distribution of Cations at 100 cm Depth as a Function of Distance from the Coast	238
37.	Map Showing Soils with Gypsum Along the Kedah River	242
38.	Map Showing Soils with Gypsum Along the Perlis River	243
39.	Soil Profile of the Chengai Series Showing the Zone of Gypsum Crystal Accumulation	250
40.	X-ray Diffractograms of the Clay and Silt Fractions of Malacca Series	270



41.	X-ray Diffractograms of the Clay and Silt Fractions of Gajah Mati Series	279
42.	X-ray Diffractograms of the Clay and Silt Fractions of Prang Series	289
43.	X-ray Diffractograms of the Clay and Silt Fractions of Pokok Sena Series	300
44.	X-ray Diffractograms of the Clay and Silt Fractions of Serdang Series	312
45.	Block Diagram of a Pediplain in Southern Kedah (Pinang Tunggal Estate, Sg. Petani)	319
46.	Lateritic Soils and Their Landscapes (P, P3 and P2 Surfaces)	320
47.	Cross-section of Pinang Tunggal Estate Showing the Major Landscape and Soil Types	334



LIST OF PLATES

Plate		Page
1.	Profile of Baging Series	79
2.	Enaulic Related Distribution in Ap Horizon of Baging Series (PPL, x25)	86
3.	Profile of the Rudua Series (W1)	89
4.	Pellicular Microstructure and Chitonic Related Distribution in the Bh Horizon of Rudua Series (W1) (PPL, x64)	99
5.	Profile of the Rudua Series (W2)	100
6.	Pellicular Microstructure in the Bh Horizon of Rudua Series (W2) (PPL, x25)	108
7.	Profile of Rudua Series (H)	110
8.	Cracked Coatings on Quartz Grains and Organic Pellets in the Spodic Horizon of Rudua Series (H) (PPL, x64)	119
9.	Profile of the Pauh Series	119
10.	Chitonic and Enaulic Related Distribution in the Pauh Series (PPL, x25)	128
11.	Tourmaline - common in all BRIS soils on Langkawi Island	128
12.	Soil Profile of the Serong Series, moderately deep phase	152

