CHARACTERISTICS, GENESIS AND CLASSIFICATION OF REDDISH SOILS FROM SIDAMO REGION OF ETHIOPIA

By

ABAYNEH ESAYAS ATENGO

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

January 2005

DEDICATION

THIS THESIS IS DEDICATED TO MY DEAREST BROTHER

Late YISMACHEW ESAYAS

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman: Associate Professor Siti Zauyah Darus, Ph D

Faculty: Agriculture

Sesquioxidic reddish soils are one of the major agricultural soils in Ethiopia. They are intensively cultivated for coffee. Accurate and detailed information on the nature and properties of these soils is necessary to improve and sustain their agricultural productivity. To achieve this objective, ten representative pedons developed from different parent materials of volcanic and metamorphic origin in Sidamo highlands, Ethiopia, were investigated.

Feldspar and ferromagnesians are the dominant minerals in the basalt, whereas quartz, feldspar and minor amounts of hornblende phenocrysts embedded in a groundmass of volcanic ash and glass are dominant in the ignimbrites and rhyolite. Zeolites (clinoptilolite and mordenite) were discovered in substantial amounts in the ignimbrites.

The soil texture, profile depth and morphology of the soils vary according to parent material groups. The soil pH values range from 4.2 to 6.8 and due to leaching of bases; soils developed under udic moisture regime have the lowest pH. The pH_{NaF} values are

generally less than 9.4, indicating that the soils are not allophanic. The cation exchange capacity (CEC) varies according to parent material groups in the order of ignimbrite > rhyolite > basalt > gneiss with the value of 4.0 to 39.6 $cmol_c$/kg soil. Exchangeable cations and available micronutrients content of the surface soils are higher than the subsurface soils. This is attributed to the cycling of nutrients by the plants. Available phosphorus (P) is low (< 6 mg P/kg soil) and it is the most limiting nutrient for crop production in the area, although copper and potassium are marginal. The P sorption studies indicated that the soils are high P sorbing soils, with the subsurface soils have higher P sorption capacity than the surface soils. The P sorption characteristics of the soils have significant positive correlation with clay content and different forms of Fe and Al, and negative correlation with soil pH. The P requirement of the surface soils varies from 41 to 142 mg P kg^{-1} soil.

The sand and silt fractions are dominated by quartz and varied amounts of feldspar. The clay fractions are dominated by kaolinite and minor amounts of illite. The relative abundance of illite and feldspar is higher in the soils from younger geological units (ignimbrites). Iron (Fe) is dominantly in crystalline form, whereas aluminium (Al) is in amorphous from in the soils. Hematite, maghemite and goethite are the common Fe-oxide minerals in the clay fractions. The relative abundance of goethite is higher in soils from higher altitudes (cooler and wetter environments). The Al substitution for Fe in hematite and goethite varied from 7 to 24 and from 14 to 39 mole % Al, respectively.

The relative proportion and distribution of coarse to fine materials (c/f-ratio) varied according to parent material groups from open porphyric in basaltic soils to single spaced porphyric in gneissic soils. Microlaminated clay coatings are abundant in soils derived from the younger geological units (ignimbrites) compared to basaltic and gneissic soils. The pedogenetic processes in the soils were mainly related to the weathering of primary minerals, clay illuviation, bioturbation and translocation of Fe-oxides to saprolitic layers. Halloysite is mainly restricted in the saprolitic layers, whereas kaolinite is dominant in the soil solum.

The Chuko and Morocho pedons, derived from Quaternary ignimbrites and characterized by appreciable clay illuviation in the B horizons are classified as Kandic Paleustalfs (Soil Survey Staff, 1999) or Profondic Lixisols (WRB, 1998), whereas the Dengora pedon derived from similar material is classified as Typic Rhodustult or Hyperdystric Acrisol due to low base saturation. The rest of the soils, due to uniform clay distribution with depth and presence of horizons of very low CEC (oxic horizon) are classified as Oxisols (Eutrustox, Eutrudox, Haplustox, Hapludox and Kandiudox) or Ferralsols (Humic Ferralsol, Rhodic Ferralsol and Hypereutric Ferralsol).

The surface charge of the soils is dominated by permanent negative charge with minor amounts of variable charge. There is an increase in AEC and a decrease in CEC with soil depth, indicating higher potential leaching losses of cations. Comparison of the fingerprint (FP) and the compulsive exchange methods indicated that the FP method can satisfactorily predict the basic nutrient retention capacity of the soils.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor falsafah

CIRI-CIRI, GENESIS DAN PENGELASAN TANAH MERAHAN DARIPADA KAWASAN SIDAMO DI ETHIOPIA

Oleh

ABAYNEH ESAYAS ATENGO

Januari 2005

Pengerusi: **Profesor Madya Siti Zauyah Darus, PhD**

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Tanah merah seskuioksida adalah tanah pertanian yang utama di Ethopia. Tanah tersebut ditanam secara intensif dengan kopi. Maklumat yang tepat dan terperinci mengenai tanah tersebut adalah sangat penting untuk memperbaiki dan mengekalkan hasil pertanian. Untuk mencapai tujuan tersebut, sepuluh pedon di kawasan tanah tinggi Sidamo, Ethopia yang terbentuk daripada bahan induk berbeza iaitu daripada volkanik dan metaforfik, telah dikaji.

Mineral utama dalam basalt ialah feldspar dan ferromagnesium. Sebaliknya kuarza, feldspar dan sedikit hornbelend finokris terdapat dalam abu volkanik dan kaca adalah dominan dalam ignimbrit and riolit. Zeolit (clinoptilolit dan mordenit) banyak terdapat dalam ignimbrit.

Tekstur tanah, kedalaman profil dan morfologi tanah adalah berbeza mengikut kumpulan bahan induk. Nilai pH tanah adalah dari 4.2 hingga 6.8 dan disebabkan larutlesap bes; tanah yag tebentuk di bawah rejim lembapan udik mempunyai pH terendah. Nilai pH_{NaF} secara keseluruhannya kurang daripada 9.4. Ini menunjukkan bahawa tanah tersebut tidak

mengandungi alofan. Nilai kadar tukarganti kation berbeza mengikut kumpulan bahan induk mengikut turutan ignimbrit > riolit > basalt > gneis dengan 4.0 hingga 39.6 $cmol_c$/kg tanah. Kation tukarganti dan kandungan mikronutrien tersedia adalah tinggi pada permukaan tanah berbanding pada lapisan bawah permukaan. Ini disebabkan oleh kitaran nutrient oleh tumbuhan. Fosforus tersedia (P) dalam tanah adalah rendah (< 6 mg P/kg tanah) dan merupakan nutrient penghad bagi hasil tanaman di kawasan tersebut walaupun kuprum dan potassium adalah marginal. Kajian terhadap jerapan P menunjukkan bahawa tanah tersebut adalah tanah penyerap P yang tinggi dan tanah lapisan bawah permukaan mempunyai kapasiti serapan P yang lebih tinggi berbanding tanah permukaan. Ciri-ciri jerapan P tanah mempunyai hubungan positif dengan kandungan lempung dan Fe dan Al dalam bentuk yang berbeza, dan mempunyai hubungan negatif dengan pH tanah. Keperluan P bagi tanah permukaan adalah dari 41 kepada 142 mg P kg^{-1} tanah.

Bahagian pasir dan kelodak didominasi oleh kuarza dan pelbagai kandungan feldspar. Bahagian lempung didominasi oleh kaolinit dan sedikit ilit. Taburan relative ilit dan feldspar lebih tinggi pada tanah dari unit geologi yang muda (ignimbrit). Ferum adalah dalam bentuk kristal, manakala aluminium (Al) dalam bentuk amorfus dalam tanah. Hematit, magnetit dan goetit adalah mineral Fe-oksida yang sering ditemui dalam bahagian lempung. Taburan goetit adalah lebih tinggi dalam tanah di kawasan altitud yang tinggi (keadaan sejuk dan lembap). Tukarganti Al untuk Fe di dalam hematit dan goetit berbeza dari 7 hingga 24 dan dari 14 kepada 39 mol % Al.

Pembahagian dan taburan relatif bahan kasar kepada halus (c/f-ratio) berbeza mengikut kumpulan bahan induk dari porphyric ruang tunggal dalam tanah gneissic. Selaput lempung berlaminamikro ditemui dengan banyak dalam tanah unit geologi muda (ignimbrit) berbanding dengan tanah basalt dan gneis. Proses pedogenik dalam tanah secara amnya berhubungkait dengan proses luluhawa mineral primer, iluvasi lempung, bioturbasi dan translokasi Fe-oksida ke lapisan saprolit. Haloisit terhad dalam lapisan saprolit. Sebaliknya kaolinit adalah dominan dalam solum tanah.

Pedon Chuko dan Morocho berasal daripada ignimbrit Kuartenari mengandungi lempung iluvasi lempung pada horizon B diklasifikasikan sebagai *Kandic Paleustalfs* (Soil Survey Staff, 1999) ataupun *Profondic Lixisol* (WRB, 1998), sebaliknya pedon Dengora diambil dari bahan yang hapir sama diklasifikasi sebagai *Typic Rhodustult* atau *Hyperdystric Acrisol* disebabkan kandungan ketepuan bes yang rendah. Tanah-tanah yang lain, mengalami pengagihan lempung yang sekata dengan kedalaman dan kehadiran horizon yang rendah KPK (horizon oxic) diklasifikasikan sebagai Oksisol (*Eutrustox, Eutrudox, Haplustox* dan *Kandiudox*) atau *Ferralsols* (*Humic Ferralsol, Rhodic Ferralsol* dan *Hypereutric Ferralsol*).

Cas permukaan tanah didominasi oleh cas cas negatif kekal dengan sedikit cas pelbagai. Terdapat peningkatan dalam AEC dan penurunan dalam CEC selaras dengan kedalaman tanah, menunjukkan potensi kehilangan kation yang lebih banyak melalui proses larutlesap. Perbandingan fingerprint (FP) dan kaedah tukarganti kompulsif menunjukkan bahawa kaedah FP dapat meramal kapasiti penahanan nutrient asas tanah.

ACKNOWLEDGEMENTS

First and foremost, my sincere gratitude and appreciation are due to my Supervisory Committee chairperson, Assoc. Prof. Dr. Siti Zauyah Darus, Head, Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia (UPM), for accepting me as a PhD student and for the professional guidance, concerned advice and constructive comments from the beginning of the research till the final submission of the thesis. I am also grateful to her for the determination to travel great distances to visit my sampling sites and for the discussions held.

I am also very much thankful to my Supervisory Committee members, Assoc. Prof. Dr. Mohd Hanafi Musa and Assoc. Prof. Dr. Rosenani Abu Bakar, Department of Land Management, Faculty of Agriculture, UPM, for their concerned follow up of the research progress, helpful suggestions, valuable comments and critical review of the manuscript. Their constant suggestions and comments have made the completion of this work possible.

I wish to thank Assoc. Prof. Dr. Che Fauziah Ishak, for allowing me to use the facilities of the Analytical Soil Laboratory. My thanks also go to Prof. Dr. Shamshuddin Jusop for providing valuable highlights on surface charge characteristics.

I wish to express my gratitude to Prof. Dr. Zaharah Abd Rahman for scheduling the seminars at convenient times and for the encouragement during my study in UPM.

Special thanks to Assoc. Prof. Dr. Anuar Abd Rahim for the lectures on GIS and for allowing me to use the facilities of GIS Laboratory. I thank En. Asri Ruslan for his help on the GIS practical lessons and preparation of maps.

I am very much thankful to the staffs of the laboratories in the Department of Land Management, Faulty of Agriculture, UPM, for their technical assistance and introduction to various instrumental techniques. Their whole-hearted help during my laboratory work has contributed a lot to the completion of my study. I wish also to express my gratitude to the administrative staff who contributed to the completion of this work in handling administrative and procurement processes. My thanks are due to the staff of Spectroscopy Laboratory, Department of Chemistry, Faculty of Science, UPM, for the technical assistance on IR analysis. My acknowledgement also goes to the staff of Microscopy and Microanalysis Unit, Laboratory of Enzyme and Microbial Technology, Institute of Bioscience, UPM, for their technical assistance during SEM and TEM examination of the samples.

I gratefully acknowledge the Ethiopian Agricultural Research Organization (EARO) for awarding me the scholarship and a study leave during my stay in Malaysia. I wish to express my gratitude to Dr. Sahlemedhin Sertu, for his valuable comments on the research proposal and continued encouragement to do the best.

My heartfelt thanks are due to the staffs of the National Soil Research Center, EARO, for their assistance during my field work and the routine soil analyses. Special thanks to Mr.

Gebeyehu Belay for his assistance during soil sampling, preparation and shipment to Malaysia. Thanks to Mr. Engida Mersha for kindly providing the meteorological data of the study area. I am also thankful to Dr. Kurkura Kabeto for the discussions on the geology of Ethiopia.

I am indebted to Mr. Roslan Ismail and Mr. Arif Sugndi for their hospitality and to be there to comfort me in times of difficulties. I am very much thankful to Mr. Ahmad Bakar (Papa) for his fatherly care to make my stay comfortable and enjoyable in Malaysia. I also wish to express my gratitude to all Ethiopian students in UPM for their assistance in times of hardships. Finally, my sincere gratitude goes to my family for their forbearance during my stay abroad.

I certify that an Examination Committee met on 05 January 2005. to conduct the final examination of Abayneh Esayas Atengo on his Doctor of Philosophy thesis entitled "Characteristics, Genesis and Classification of Sesquioxidic Soils From Sidamo Region of Ethiopia" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for the quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted to any other degree at UPM or other institutions.

ABAYNEH ESAYAS ATENGO

Date:

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