UNIVERSITI PUTRA MALAYSIA

PROPERTIES, GENESIS AND CLASSIFICATION OF SOILS ON VOLCANIC MATERIALS IN LEMBANG AREA, WEST JAVA, INDONESIA

EDI YATNO

FP 2003 13

PROPERTIES, GENESIS AND CLASSIFICATION OF SOILS ON VOLCANIC MATERIALS IN LEMBANG AREA, WEST JAVA, INDONESIA

EDI YATNO

MASTER OF AGRICULTURAL SCIENCE
UNIVERSITI PUTRA MALAYSIA

2003

PROPERTIES, GENESIS AND CLASSIFICATION OF SOILS ON VOLCANIC MATERIALS IN LEMBANG AREA, WEST JAVA, INDONESIA

By

EDI YATNO

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Agricultural Science

July 2003

This thesis is specially dedicated to my beloved parents :

Hj. Garyanti

and

late Sudharsono

who always supported and encouraged me to do the best

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Agricultural Science

PROPERTIES, GENESIS AND CLASSIFICATION OF SOILS ON VOLCANIC MATERIALS IN LEMBANG AREA, WEST JAVA, INDONESIA

By

EDI YATNO

July 2003

Chairman : Associate Professor Siti Zauyah Darus, Ph.D.

Faculty : Agriculture

Soils developed on volcanic materials have high potential for agricultural production. However, the productivity of some of them is below their potential capacity. Proper management of these soils must be based on understanding their nature and properties. Lembang is one of the most intensively cultivated areas for horticultural crops, tea and pine trees in West Java, Indonesia. Unfortunately, data on the characteristics of soils developed on different volcanic materials of different ages in this area are still limited. Thus, six representative soil profiles developed on andesitic volcanic ash and tuff were studied. The objectives of this study were to determine the soil physical, chemical, mineralogical and micromorphological properties, to relate the soil properties to soil-forming processes and to classify the soils according to Soil Taxonomy and World Reference Base.

The results of this study show that all the soils have very deep solum (>150 cm). Some soil profiles developed on volcanic ash have buried organic-rich horizons

as a result of repeated thin ash deposition. In general, the volcanic ash soils are darker coloured, more granular, more friable, less sticky and less plastic than the volcanic tuff soils. The ash soils generally have silt loam to clay loam textures, while the tuff soils have clay texture. The ash soils have lower bulk density (0.38 to 0.79 Mg/m^3), higher total porosity (55 to 84%) and higher available water content (13.0 to 34.6%) than the tuff soils.

The pH_{H2O} of the soils ranges from 3.52 to 5.88. Some soil profiles in both parent materials show high exchangeable Al (2.2 to 5.9 $cmol_c/kg$). The ash soils have higher pH_{NaF} (> 9.4), higher organic carbon (up to 10%), and higher phosphate retention (> 85%) than the tuff soils. The high values of pH_{NaF} and phosphate retention in the volcanic ash soils are related to the presence of large amounts of amorphous Al. The CEC is generally higher in the ash soils (22 to 46 $cmol_c/kg$) than in the tuff soils (18 to 31 $cmol_c/kg$). The base saturation is generally low (< 15%) in the upper horizons of all the soils.

The sand fractions of the ash soils are dominated by hornblende, while the tuff soils are predominantly composed of opaque minerals or magnetite. In the silt fractions, all the soils in both parent materials show traces to minor amounts of cristobalite, tridymite and quartz. Gibbsite is only observed in the loamy tuff profile, while hydrated halloysite is only present in the lower horizons of another tuff profile. In the clay fractions, the ash soils are dominated by allophane with varying amounts of cristobalite, whereas the tuff soils show a high content of gibbsite and metahalloysite.

Thin sections of the soils show that most horizons of the ash soils have granular microstructures. In the tuff soils, however, the microstructures are only observed in the surface horizons, while most of the subsurface horizons of the soils exhibit subangular blocky microstructures. The rock fragments and primary minerals such as hornblende are larger and less weathered in the ash soils than in the tuff soils. Some excrements and phytoliths are observed in the upper part of some soil profiles developed on volcanic ash. All the soils have no clay cutans.

Soil-forming processes of the soils studied are related to the type and age of parent materials. The soil-forming processes that influence the development and properties of the younger volcanic ash soils are weathering of volcanic ash to allophane, addition of new ash materials and accumulation of organic matter. In contrast, the soil-forming processes which occur in the volcanic tuff soils are addition of mineral materials, alteration of ferromagnesian minerals to iron oxides, alteration of feldspar to metahalloysite and desilication of feldspar to gibbsite.

Soils developed on volcanic ash are classified as Thaptic Hapludands and Typic Melanudands according to Soil Taxonomy (Soil Survey Staff, 1999) or Thapto-Silic Andosols and Melano-Silic Andosols according to World Reference Base (ISSS-ISRIC-FAO, 1998). Soils formed from volcanic tuff, however, are classified as Andic Dystrudepts (Soil Taxonomy) or Hyperdystri-Silandic Cambisols, Orthidystric Cambisols and Hyperdystric Cambisols (World Reference Base).

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains Pertanian

SIFAT-SIFAT, GENESIS DAN PENGELASAN TANAH-TANAH TERBENTUK DARI BAHAN VOLKANIK DI KAWASAN LEMBANG, JAWA BARAT, INDONESIA

Oleh

EDI YATNO

Julai 2003

Pengurusi : Profesor Madya Siti Zauyah Darus, Ph.D.

Fakulti : Pertanian

Tanah terbentuk daripada bahan volkanik berpotensi tinggi untuk mengeluarkan hasil pertanian. Walaubagaimanapun, sesetengah daripadanya adalah di bawah potensi sebenar. Pengurusan tanah yang baik memerlukan kefahaman tentang sifat semulajadi tanah tersebut dan ciri-cirinya. Lembang merupakan salah satu kawasan penanaman hortikultur, teh dan pokok pain yang pesat di Jawa Barat, Indonesia. Malangnya, maklumat tentang tanah volkanik yang berbeza umur di kawasan ini masih lagi berkekurangan. Oleh itu, enam profil tanah terbentuk daripada abu dan tuf volkanik andesit telah dikaji. Objektif kajian ini ialah untuk menentukan sifat-sifat fizik, kimia, mineralogi dan mikromorfologi tanah, mengaitkan sifat ini dengan proses pembentukan tanah dan mengkelaskannya mengikut "Soil Taxonomy" dan "World Reference Base".

Hasil kajian menunjukkan bahawa kesemua tanah mempunyai solum yang dalam (> 150 cm). Sesetengah profil tanah yang terbentuk daripada abu volkanik mempunyai horizon yang kaya dengan bahan organik hasil daripada longgokan abu

nipis yang berulang. Tanah abu volkanik berwarna lebih gelap, lebih bergerintil, lebih gembur, kurang melekit dan kurang berplastik berbanding tanah tuf volkanik. Tanah abu volkanik mempunyai tekstur lom berkelodak ke lom lempung, sedangkan tanah tuf volkanik mempunyai tekstur lempung. Tanah abu volkanik mempunyai ketumpatan pukal rendah (0.38 ke 0.79 Mg/m^3), ruang liang tinggi (55 ke 84%), dan kandungan kelembapan tinggi (13.0 ke 34.6%) berbanding tanah tuf volkanik.

pH_{H2O} kesemua tanah adalah dalam lingkungan 3.52 ke 5.88. Sesetengah profil tanah dari kedua-dua bahan induk menunjukkan Al tukarganti yang tinggi (2.2 ke 5.9 $cmol_c/kg$). Tanah abu volkanik mempunyai nilai pH_{NaF} yang tinggi (> 9.4), kandungan karbon organik yang tinggi (sehingga 10%), dan pengikatan fosfat yang tinggi (> 85%) berbanding tanah tuf volkanik. Nilai pH_{NaF} dan pengikatan fosfat yang tinggi di dalam tanah abu volkanik ada kaitan dengan kehadiran sejumlah besar Al amorfus. KPK adalah tinggi dalam tanah abu volkanik (22 ke 46 $cmol_c/kg$) berbanding tanah tuf volkanik (18 ke 31 $cmol_c/kg$). Kepekatan bes adalah rendah (< 15%) pada horizon atas profil tanah.

Bahagian pasir tanah abu volkanik mengandungi banyak hornblen, sementara tanah tuf volkanik mempunyai banyak mineral tak tersinar atau magnetit. Dalam bahagian kelodak, kesemua tanah dalam kedua-dua bahan induk ini menunjukkan sedikit kristobalit, tridimit, dan kuarza. Gibsit cuma dapat dilihat dalam profil tanah tuf volkanik berlom, sementara haloisit terhidrat hadir cuma pada horizon bawah salah satu profil tuf. Dalam bahagian lempung, tanah abu volkanik mengandungi banyak alofan dan kuantiti kristobalit yang berbeza, sedangkan tanah tuf volkanik mengandungi banyak gibsit dan metahaloisit.

Keratan nipis tanah menunjukkan bahawa kebanyakan horizon tanah abu volkanik mempunyai mikrostruktur bergerintil. Walaubagaimanapun, dalam tanah tuf volkanik, mikrostruktur ini cuma dilihat pada horizon atas, sedangkan kebanyakan horizon bawah mempamerkan mikrostruktur blok bersudut. Serpihan batuan dan mineral primer seperti hornblen adalah lebih besar dan kurang terluluhawa dalam tanah abu volkanik berbanding tanah tuf volkanik. Sebahagian kumuhan dan pitolit terdapat pada bahagian atas profil terbentuk daripada abu volkanik. Kesemua tanah tiada kulit lempung.

Proses pembentukan tanah yang dikaji ada kaitan dengan jenis dan umur bahan induk. Proses pembentukan tanah yang mempengaruhi pembentukan dan ciri-ciri tanah abu volkanik yang lebih muda ialah luluhawa abu volkanik kepada alofan, penambahan bahan abu baru dan pengumpulan bahan organik. Sebaliknya, proses pembentukan tanah yang berlaku dalam tanah tuf volkanik ialah penambahan bahan mineral, perubahan mineral feromagnesian kepada oksida besi, perubahan feldspar kepada metahaloisit dan nyahsilika feldspar ke gibsit.

Tanah terbentuk daripada abu volkanik diklasifikasikan sebagai *Thaptic Hapludands* dan *Typic Melanudands* mengikut "Soil Taxonomy" (Soil Survey Staff, 1999) atau *Thapto-Silic Andosols* dan *Melano-Silic Andosols* mengikut "World Reference Base" (ISSS-ISRIC-FAO, 1998). Tanah terbentuk daripada tuf volkanik pula, diklasifikasikan sebagai *Andic Dystrudepts* (Soil Taxonomy) atau *Hyperdystri-Silandic Cambisols*, *Orthidystric Cambisols* dan *Hyperdystric Cambisols* (World Reference Base).

ACKNOWLEDGEMENTS

In the name of Allah the Most Merciful and Most Compassionate. Praise is to Allah s.w.t, for giving His help and guidance throughout my study.

First and foremost, I am indebted to my supervisor, Assoc. Prof. Dr. Siti Zauyah Darus, Head of Department of Land Management, Faculty of Agriculture, UPM, for her supervision, advice, guidance, understanding, encouragement and constructive criticism throughout the study.

I am also grateful to the members of my supervisory committee, Assoc. Prof. Dr. Che Fauziah Ishak and Mr. Peli Mat at the Department of Land Management, UPM, for their valuable comments and suggestions. And a special thanks to Prof. Shamshuddin Jusop at the Department of Land Management, UPM, as the chairman of the Examination Committee for his constructive ideas. My appreciation also goes to all the lecturers and support staffs of the Department of Land Management and the Graduate School Office for their assistance.

My sincere gratitude is also extended to the Participatory Development of Agricultural Technology Project (PAATP, Asian Development Bank Loan) of the Agency for Agricultural Research and Development (AARD), Government of Indonesia for giving me the opportunity, funding and support throughout my study at Universiti Putra Malaysia.

I would like to thank Director of AARD (Dr. Djoko Budiyanto), Director of the Committee of Human Resources Development (Dr. Muhamad Djoko Said Damardjati), PAATP Leaders (Dr. Haryono and Dr. Marhendro), Director of Centre for Soil and Agroclimate Research and Development (Dr. Abdurachman Adimihardja) and Director of Soil Research Institute (Dr. Fahmuddin Agus) for their support and encouragement. I am also grateful to the PAATP Training Division Staffs for their assistance.

My deepest gratitude goes to my parents, sisters, and my family for their prayers, encouragement and help during my studies. Finally, I am indebted to a lot of people who helped me throughout my studies, "May Allah reward them for their good deeds, Ameen".

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The Indonesian archipelago is predominantly mountainous with some 400 volcanoes, of which 129 are active. Twenty-one of these volcanoes are located in West Java (Van Bemmelen, 1970). The activity of these volcanoes may produce various volcanoclastic materials such as ash, tuff, pumice, cinders, lahars and other volcanic ejecta.

The beneficial effects of volcanic eruption are often more subtle, occurring on a geologic time-scale rather than during the lifetime of an individual. The development and rejuvenation of soils provide an environment favourable to the eventual establishment of lush vegetation and the ecology of organisms, including human beings. The periodic additions of volcanic ash renew the long-term fertility status by providing a source of nutrients from the rapid weathering of ash (Shoji *et al*., 1993a).

Soils formed from volcanic materials have many distinctive properties that are rarely found in soils derived from other parent materials (Wada, 1986). These soils have high potentials for agricultural production. However, some of them produce well below their potential capacity due to lack of understanding of the nature and properties and proper management of these soils.

Soils developed on volcanic materials are generally classified as Andisols, but not all volcanic soils are Andisols. It depends on the weathering and soil formation processes (Shoji *et al*., 1993a). Andisol is a soil developed from volcanic ejecta (such as volcanic ash, pumice, cinders, lava), and/or from volcanoclastic materials, with colloidal fraction that is dominated by short-range-order minerals of Al-humus complexes (Mizota and Van Reeuwijk, 1989). Andisols have been characterized by high organic carbon content, low bulk density, high P retention, high CEC (Otawa, 1986), high pH_{NaF}, and high oxalate extractable Al (Al_o) and Si (Si_o) content (Balsem and Buurman, 1990).

Volcanic ash soils are among the most productive in the world. The chemical and physical properties of these soils influence their productivity in various ways (Shoji *et al*., 1993b). Accurate and detailed information on these properties is therefore necessary for developing programmes for improving productivity, sustainable utilization and conservation of these soils.

Lembang is one of the most intensively cultivated areas for horticultural crops, tea and pine trees in West Java, Indonesia. The agricultural practice carried out in the areas was based on semi-scientific agrotechnology or medium input farming. Soils of this area are developed on different volcanic materials of different ages. The distinctions may result in different characteristics of the soils. As a consequence, the productivity of the soils may also be different. Unfortunately, data on the characteristics of these soils, in the Lembang area, are rather limited. Thus, it is important to study these soils to give a more accurate information of their behaviour and performance to support soil management.

1.2 Objectives of the Study

The objectives of this study on soils derived from volcanic materials in the Lembang area (West Java), Indonesia were:

1. To determine the physical, chemical, mineralogical, and micromorphological properties of soils developed on two types of volcanic materials (ash and tuff) from Lembang area, West Java;

2. To relate the soil properties to soil-forming processes, parent materials and fertility status; and

3. To classify the soils according to Soil Taxonomy (Soil Survey Staff, 1999) and World Reference Base for Soil Resources (ISSS-ISRIC-FAO, 1998).

CHAPTER 2

LITERATURE REVIEW

2.1 Geographic Distribution of Soils on Volcanic Materials

The distribution of soils derived from volcanic materials closely parallels with global distribution of active and recently active volcanoes (Shoji *et al.*, 1993a). Volcanic ash soils cover approximately 124 million hectares or 0.84% of the world's land surface (Leamy, 1984). Approximately 60% of volcanic ash soils occur in tropical countries. In Indonesia, the soils are distributed from Sumatra in the west, over Java and to the Lesser Sunda Islands (Bali, Lombok, Sumbawa and Flores) in the east (Tan, 1965).

The Indonesian archipelago is one of the most active volcanic areas of the world. There are about 129 active volcanoes in this country (Van Bemmelen, 1970). Based on their historical activities, the active volcanoes in Indonesia are classified into three types: (1) Type A : volcanoes, which have had magmatic or phreatic eruptions since 1600, (2) Type B : volcanoes, which have had no magmatic or phreatic eruptions since 1600, but have fumarolic and solfataric activities, and (3) Type C : volcanoes with no activities evident except slight or minor fumarolic and solfataric activities. Eighty of the above volcanoes have been classified into A type according to their recorded-eruptions since 1600. These are located across Sumatra (12 volcanoes), Java (21), Bali (2), Nusa Tenggara (20), Banda Sea (9), North Sulawesi (6), Sangihe (5), and Halmahera (5). The distribution of the volcanoes in Indonesia is shown in Figure 2.1.