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SOIL GENESIS, CLASSIFICATION AND SOIL-CROP SUITABILITY OF SERDANG AND MALACCA SOIL SERIES IN A MALAYSIAN PUBLIC UNIVERSITY

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By

SANTURAKI HASSAN ALIYU

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

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Chairman : Roslan bin Ismail, PhD
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A study was conducted to update the soil data of Serdang and Malacca Series. The soil data update was conducted in order to obtain comprehensive soil data for characterization of physical, chemical and mineralogical properties of Serdang Series (Ultisols Order) and Malacca Series (Oxisols Order) and within UPM campus area. The soil data were used for Soil-Crop Suitability assessment as stated by Wong (2009) and FAO Land Evaluation (1976) that benefits farmers, soil scientist and to some extent, benefits stakeholders in future soil studies. A total of four soil profiles were dug that, represent Serdang and Malacca Series. For each soil series, the soil profile represent two condition, which are minimal disturbance and highly disturbed soil condition. Following the soil profile preparation, the soil classification was conducted based on USDA Soil Taxonomy (Soil Survey Staff, 2014).

Bulk density and porosity are important physical properties of soil. For Serdang Series, highly disturbed soils have higher bulk density (1.47-1.51 g cm^{-3}) values compared to minimal disturbance (1.42-1.47 g cm^{-3}). This indicate top soil soil compaction after several years of human activity, and further supported with reduction (from 38% to 30%) in soil porosity. Compaction decreases porosity as bulk density increases. Typically, porosity between 40-50% would be ideal for soil, to support good plant growth. In general, if compaction increases bulk density from 1.3 to 1.5 g/cm3, porosity decreases from 50 percent to 43 percent. Aggregation also decreases porosity because more large pores are present as compared to single clay and silt particles that are associated with smaller pores.

Another important aspect of soil porosity concerns the oxygen found within these pore spaces. All plants need oxygen for respiration, so a well-aerated soil is important for growing crops. For Malacca Series, the bulk density was

lower compared to Serdang Series, and thus increase in porosity (from 35% to 41%) was observed. This support that, Malacca Series have better potential to be utilized for plant growth compared to Serdang Series in terms of soil physical criteria.

Soil chemical properties, such as soil pH for both soil series indicated the soil were strongly (pH 4) to moderately acidic (pH 5.6) in reaction. Cation exchange capacity (CEC) values of all the soil were low (< 16 $cmol_{+}$ kg^{-1}). The values ranged from 11.0 to 5.25 $cmol_{+}$ kg^{-1} and 8.72 to 4.16 $cmol_{+}$ kg^{-1} and 10.22 to 4.66 $cmol_{+}$ kg^{-1} and 9.72 to 3.38 $cmol_{+}$ kg^{-1} [1] for the highly and minimally disturbed soil of Serdang and Malacca Series. Base saturation values were also low for all soils (< 50%), available phosphorus, total nitrogen contents (0.15-0.20%) of all the soil were moderately low. Except for organic carbon, average of 3.5% was observed for minimal disturbed soils for both series, compared to highly disturbed with reduction of half a magnitude. Exchangeable aluminum values were higher in Serdang Series (1.59-2.66 $cmol_{+}$ kg^{-1}) indicating high level of potential soil toxicity if the aluminium becomes available for plant uptake in the soil. At present, the aluminium poses moderate concerns for plant, with lime application is recommended in Malaysia to mitigate the aluminium saturation to certain extent. As such practice is used widely in Malaysian soil for oil palm, rubber, paddy and other crop production.

Mineralogical data showed presence of kaolinite, gibbsite and quartz in both Serdang Series and Malacca Series that indicates highly weathered soil in Malaysia tropical region. Meanwhile, soil texture class indicates sandy clay loam to sandy clay for both Serdang and Malacca Series, and under this textural class, the soils can be stated as moderately fine, that require some tillage practice for good crop growth. Serdang Series and Malacca Series, respectively classified as Typic Kandiudults and Typic Hapludox, based on USDA Soil Taxonomy (Soil Survey Staff, 2014).

Assessment of Soil-Crop Suitability based on Wong (2009) on the selected crops that are oil palm, cocoa, rubber, corn and paddy were conducted for both soil series. The assessment noted that, Serdang Series were Marginally (M) suitable (nutrient imbalance) with Class 2n for all the selected crop production compared to Malacca Series. Class 2 indicates one moderate limitations. Malacca Series noted to be Unsuitable (U) with Class 4 (nc)r for all the selected crops mainly due to nutrient imbalance (n), soil compaction (c) and stoniness (r) within the soil layers. Nutrient imbalance (n) limitations can be improved with application of inorganic NPK fertilizer, compost, lime and some other soil amendment. With that, the Malacca Series can be improved to potential suitability of Class 4 cr. Class 4 indicates at least one very serious limitations. Since the limitations c and r falls within the physical limitations. Rectification of such limitation are often costly. Therefore, perennial crops such as oil palm, rubber and cocoa have a better potential to be cultivated in Malacca Series compared to cash crops such as corn and paddy.

Meanwhile, based on FAO (1976) suitability indices, Serdang Series are marginally suitable with nutrient imbalance (Sf) for all selected crops, compared to Malacca Series that indicates oil palm and cocoa are unsuitable for planting crops (N), while rubber is marginally suitable with nutrient deficiency (Sf). The FAO system of classification indicates soil limiting factors for each particular crop, while system of classification in Wong is based on the group of crops that match with each soil suitability class. As a conclusion, Serdang Series are marginally suitable for perennial and cash crops production compared to Malacca series, that only suitable for rubber growth. With soil amendments, Malacca Series can be potential for oil palm and cocoa production.

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

GENESIS TANAH, PENGKELASAN DAN KESESUAIAN TANAH-TANAMAN BAGI SIRI SERDANG DAN MELAKA DI UNIVERSITI AWAM MALAYSIA

Oleh

SANTURAKI HASSAN ALIYU

Februari 2017

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Satu kajian telah dijalankan bagi mengemaskini data tanah siri Serdang dan siri Melaka. Pengemaskinian data dijalankan bagi mendapatkan data pencirian menyeluruh bagi sifat-sifat fizikal, kimia dan mineralogi tanah siri Serdang (Order Ultisol) dan siri Melaka (Order Oxisol) dalam kawasan kampus UPM. Data pencirian tersebut digunakan dalam penilaian Keseseuaian Tanah-Tanaman seperti dinyatakan oleh Wong (2009) dan FAO Land Evaluation (1976) untuk manfaat oleh petani, penyelidik dan pihak berkepentingan dalam penyelidikan di masa hadapan. Empat profil tanah digali bagi mewakili tanah siri Serdang dan Melaka. Bagi setiap siri tanah, profil mewakili dua jenis keadaan iaitu tanah pada gangguan paling minimal dan sangat terganggu. Susulan kepada penyediaan profil tanah tersebut, pengkelasan tanah dijalankan berdasarkan garis panduan oleh USDA Soil Taxonomy (Soil Survey Staff, 2014).

Ketumpatan pukal dan keliangan merupakan ciri fizikal yang penting. Bagi siri Serdang, tanah dengan keadaan sangat terganggu mempunyai nilai ketumpatan pukal lebih tinggi (1.47-1.51 g cm^{-3}) berbanding tanah dengan gangguan minimal (1.42-1.47 g cm^{-3}). Ini menunjukkan bahawa berlaku pemadatan tanah akibat aktiviti manusia dan teori ini dikukuhkan lagi dengan penurunan nilai keliangan (daripada 38% kepada 30%). Pemadatan tanah menurunkan peratus keliangan dan meningkatkan nilai ketumpatan pukal. Secara tipikalnya, keliangan sebanyak 40-50% amat bersesuaian bagi menyokong pertumbuhan tanaman. Secara keseluruhannya, sekiranya pemadatan meningkatkan ketumpatan pukal daripada 1.3 kepada 1.5 g/cm^3, nilai keliangan berkurang daripada 50% kepada 43%. Pengagregatan juga merendahkan nilai keliangan kerana kewujudan lebih banyak liang besar berbanding zarah liat dan kelodak yang berkaitan dengan liang bersaiz kecil.

Aspek penting lain dalam keliangan berkait rapat dengan jumlah oksigen yang didaapti dalam ruang liang-liang tersebut. Tanaman memerlukan oksigen bagi tujuan respirasi, maka tanah dengan pengudaraan yang baik adalah penting bagi pertumbuhan tanaman. Bagi siri Melaka, ketumpatan pukalnya adalah lebih rendah berbanding siri Serdang, dengan itu terdapat peningkatan keliangan (daripada 35% kepada 41%). Siri Melaka mempunyai potensi lebih tinggi untuk digunakan bagi pertumbuhan tanaman berbanding siri Serdang daripada segi ciri-ciri fizikalnya. kuat (pH 4) ke sederhana berasid (pH 5.6) dalam tindak balas. Nilai kadar pertukaran kation (KPK) bagi kedua-dua siri adalah rendah (< 16 $cmol_+$ kg^{-1}). Nilainya dalam julat 11.0 kepada 5.25 $cmol_+$ kg^{-1} dan 8.72 kepada 4.16 $cmol_+$ kg^{-1} dan 10.22 kepada 4.66 $cmol_+$ kg^{-1} dan 9.72 kepada 3.38 $cmol_+$ kg^{-1} bagi tanah sangat terganggu dan gangguan minimal untuk siri Serdang dan Melaka. Nilai ketepuan bes juga rendah bagi semua jenis tanah (< 50%), manakala nilai fosforus tersedia dan nitrogen total (0.15-0.20%) adalah sederhana rendah. Purata karbon total sebanyak 3.5% didapati pada tanah dengan gangguan minimal bagi kedua-dua siri tanah, berbanding tanah sangat terganggu dengan pengurangan separuh magnitud. Nilai aluminium tukarganti lebih tinggi dalam tanah siri Serdang (1.59-2.66 $cmol_+$ kg^{-1}), menunjukkan bahawa nilai aluminium berpotensi menghasilkan ketoksikan tanah di kawasan tersebut. Buat masa ini, aluminium tidak menjadi isu besar buat pertumbuhan tanaman dengan adanya aplikasi kapur bagi mengekang ketoksikan aluminium dalam tanah. Amalan ini dilaksanakan secara meluas di Malaysia bagi tanaman kelapa sawit, getah, padi dan tanaman lain.

Data mineralogi menunjukkan bahawa terdapat kewujudan kaolinite, gibbsite dan quartz dalam tanah siri Serdang dan Melaka, menunjukkan tanah Malaysia merupakan tanah yang terluluhawa dalam cuaca tropika. Selain itu, pengkelasan tekstur tanah menunjukkan bahawa siri Serdang dan siri Melaka mempunyai tekstur tanah liat gembur berpasir dan liat berpasir. Berdasarkan pengkelasan tekstur ini, tanah boleh dikategorikan sebagai baik dan memerlukan hanya sedikit amalan pembajakan untuk pertumbuhan tanaman. Siri Serdang dan siri Melaka, masing-masing dikategorikan sebagai Typic Kandiudults dan Typic Hapludox, berdasarkan kepada garis panduan oleh USDA Soil Taxonomy (Soil Survey Staff, 2014).

Penilaian Soil-Crop Suitability oleh Wong (2009) bagi tanaman terpilih seperti kelapa sawit, koko, getah, jagung dan padi dijalankan bagi kedua-dua siri tanah. Penilaian mendapati bahawa siri Serdang adalah sedikit (M) sesuai (ketidakseimbangan nutrien) dengan kelas 2n bagi kesemua tanaman terpilih. Kelas 2 menunjukkan bahawa terdapat satu had pada tanah tersebut. Siri Melaka didapati tidak sesuai (U) dengan kelas 4 (nc)r bagi kesemua jenis tanaman terpilih kerana ketidakseimbangan nutrien (n), pemadatan tanah (c) dan tekstur berbatu (r) dalam lapisan tanah tersebut. Ketidakseimbangan nutrien (n) boleh diatasi dengan aplikasi baja kimia NPK, kompos, kapur dan bahan penambahbaik tanah lain. Kesesuaian siri Melaka mampu ditingkatkan kepada Kelas 4 cr. Kelas 4 menunjukkan bahawa sekurang-kurangnya terdapat satu had pengeluaran. Memandangkan had c dan r merupakan had daripada segi ciri fizikal, pembetulan bagi tanah tersebut adalah mahal. Oleh itu, tanaman saka seperti kelapa sawit, getah dan koko berpotensi untuk ditanam atas tanah siri Melaka berbanding tanaman kontan seperti jagung dan padi.

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I certify that a Thesis Examination Committee has met on 21 February 2017 to conduct the final examination of Santuraki Hassan Aliyu on his thesis entitled "Soil Genesis, Classification and Soil-Crop Suitability of Serdang and Malacca Soil Series in a Malaysian Public University" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the supervisory committee were as follows:

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LIST OF ABBREVIATIONS

SHC	Saturated hydraulic conductivity
BD	Bulk density
WHC	Water holding capacity
EC	Electrical conductivity
CEC	Cation exchange capacity
BS	Base saturation
AP	Available phosphorus
Al	Exchangeable aluminium
Al^{3+} sat	Aluminium saturation
TN	Total nitrogen
S_{hd}	Serdang highly disturbed
S_{md}	Serdang minimally disturbed
M_{hd}	Malacca highly disturbed
M_{md}	Malacca minimally disturbed

CHAPTER 1

INTRODUCTION

1.1 Background of the study area

Universiti Putra Malaysia is located in Serdang, Selangor, Peninsular Malaysia. It has total land area of about 1108 hectare and consists of many facilities such as farms, buildings, hostels, playground, lakes, hospital, golf course, stadium and swimming pool. The Universiti Farms have been classified into sixteen fields in which all are within the University and are used for students research and learning (Paramananthan et al., 1979). Some portion of the land is used for research, student learning and training (Jusop and Darus, 1979).

In University's Farm, the important factor affecting soil geneses are the parent material and climate. Soil forms from the mineral rocks are broken up from the parent rock through the process of weathering and plants roots. The formation of soil is influenced by climate, parent material, topography, biota and time. The agent of weathering is water, glacial, gravity, lakes and ice (Edward Plaster, 2014). Soil of Universiti Putra Malaysia are derived from Kenny Hill, Kajang Hill and Kuala Lumpur hill. Kenny Hill consist of quartzite and phyllite, Kajang Hill consist of schist with minor intercalation of limestone and phyllite while Kuala Lumpur Hill consist of limestone with minor intercalation of phyllite (Yin, 1976). The soil of Universiti Farm contains iron rich parent material such as schist and shale in the northern part of the farm. Meanwhile, sandstone and quartzite interbedded with schist dominate the southern part of the University Farms. Ultisols and Oxisols contain about 72% of Malaysia Soils. They are highly weathered soil as a result of high rainfall and temperature. Ultisols derived from older alluvium and sub-recent alluvial deposits which consist of shale and sandstone. Oxisols derived from basalt, gabbro and schist (Shamshuddin and Markus, 2008). Ultisols are normally yellowish in colour while Oxisols are normally reddish in colour (Shamshuddin and Che Fauziah, 2010). In subsoil the present of argillic horizon Bt that indicates Ultisols in which the clay from the top soil has leached and accumulated in the B horizon. Oxisols indicates the presence of oxic horizon (Bo) in the subsurface soil (Shamshuddin et al., 2011). Ultisols shows moderately strong sub angular to strong sub angular blocky structures while Oxisols have weak sub angular blocky structures. About 70% of these soils have deep profiles at times up to two metre and are highly leached.

Aluminium (Al^{3+}) and iron (Fe^{2+}) are dominant on the soil surface which makes the soil to be low in pH. The pH are naturally acidic ranging from 4-5 with Ultisols has lower pH than Oxisols due to aluminium hydrolysis dominate the soil reaction in Ultisols (Shamshuddin and Che Fauziah, 2010). High aluminium saturation content cause toxicity and low productivity of crops yield and growth more especially intolerant crops (Shamshuddin and Kapok, 2010). Cation exchange capacity (CEC) is low reason being that basic cations will not hold the clay soil negative charge instead they will leached into the soil, also base saturation is normally lower in Oxisols when compare to Ultisols due to high weathered of basic cations in Oxisols. Organic matter content that supplies the plants nutrients for proper development and growth is low in both soils which will decrease the activities of microorganism more in subsoil profile than on top soil surface. Both soils contain positive and negative charges, usually negative charge is more pronounce in Ultisols than positive charge while positive charge is more pronounce than negative charge in Oxisols (Anda et al., 2008).

1.2 Soil classification

Soil classification serve as a tool for grouping soil based on their chemical and morphological properties (Soil Survey Staff, 2014). The most important factor widely used in soil classification is the Soil Taxonomy of United States Department of Agriculture (USDA) (Schonover and Crim, 2015). Soil classification shows the relationship within group of soil and classified them based on their physical, chemical biological properties (Eswaran et al., 2002). Soil Taxonomy is part of soil classification that was developed to create hierarchies of soil group which can be used to test the correlation among different soil types. Soil Taxonomy used to describe the different kind of soil properties that are found in the environment which are group and named for easier communication (USDA, 1975).

The Soil Taxonomy of Malaysia was developed by Paramananthan, (1998). The system is adopted principle of hierarchy of soil from order to series. Malaysian Soil Taxonomy is designed, organized and arranged based on Soil Survey Staff (1975) with some little changes of condition that will be suitable for Malaysian soil (Paramananthan, 2000). Serdang Series is classified as Ultisols while Malacca Series is classified as Oxisols (Craswell and Pushparajah, 1989).

Diagnostic horizon is an important factor in soil classification system that provides various soil taxa and gives strong information of soils. The diagnostic horizon of surface and subsurface classified soil based on their physical, chemical and moisture regime of that environment (Eswaran, 2002). Argillic horizon (Ultisols) has high content of clay that illuviated from the surface which shows presence of clay skin and indicates highly weathered soils (Ibrahim, 2011). Oxic horizon (Oxisols) developed in subsurface layer which contained oxides of iron and aluminium (Shamshuddin and Che Fauziah, 2010).

1.3 Farming activities

The farming activities in Farm 15, UPM is currently cultivated with many varieties of crops. The Farm area consists of two portions, one portion is highly disturbed and the other portion is minimally disturbed.

The highly disturbed area is mainly use for student trial plot, research and farming. The activities in the area involve ploughing the soil, planting, application of fertilizer, application of pesticides and harvesting the crops. This disturbance is due to agricultural activities.

The minimally disturbed area was used for planting posture once in the entire UPM's history. There is no any activity involved in the Farm for long period of time. This disturbance is due to agricultural activities.

1.4 Problem statement

Agriculture plays a central role in Malaysia's economic. About 11% of gross domestic product is from agriculture (Rahman, 2012). Agriculture supply essential food to the people, give employment and raw material for agro-based industries. Declined in food production as a result of infertility of the soils in the country can result rise in amount of food crops and will have consequences on the people (Razak et al., 2013).

The acid soil (like Oxisols and Ultisols) dominates approximately 72% of Malaysian soil is a serious problem in agricultural system of Malaysian soil. These soil cause leaching of basic cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}) and sodium (Na^{+}) and accumulation of hydrogen and aluminium ions which make the soil infertile with poor nutrients content. Serdang and Malacca soil series contain low cation exchange capacity, low soil pH and high aluminium and hydrogen ions which affect the growth and production of food crops (Shamshuddin and Kapok, 2010). The toxicity of these aluminium and hydrogen inhibited growth of root crops, cell division and abnormalities within the chromosomes of plants. It also prevents root tips elongation, stomata conductance, stunting, purpling of leaves stem and late maturity. To increase the yield production it's require to conserve the soil for future use. The selected mineral soil was last updated by Paramananthan et al. (1979). Other than for internal reference in the future, it is significant to classify the soil in a way that the information of the soil characteristics will be transferred and help ease communication with farmers, soil scientists and stakeholders.

1.5 Objectives of the research

1. To characterize the soil profiles of selected (Serdang and Malacca Series) mineral soils in the Farm 15, UPM campus.
2. To determine the physical, chemical and mineralogical properties and their subsequent changes over time of Serdang and Malacca Series in UPM campus.
3. To evaluate the soil for crop suitability based on local system of Wong (2009) and international system of Food and Agriculture Organization (FAO, 1796).

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