UNIVERSITI PUTRA MALAYSIA

OCCURRENCE, PROPERTIES AND SUITABILITY OF SANDY BEACH RIDGES (BRIS) SOILS IN THE KELANTAN-TERENGGANU PLAINS, PENINSULAR MALAYSIA

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

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Abstract of the 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 : Prof. Shamshuddin Jusop, PhD

Faculty : Agriculture

A study was conducted to understand the occurrence, properties and productivity of the sandy beach ridges (BRIS) soils in the Kelantan-Terengganu Plains, Peninsular Malaysia. It consist of Baging, Rusila, Rhu Tapai (profile P1), Rudua (profile P2) and Jambu Series (profile P3). Three of the latter soil series have spodic horizon at different depth, hence classified as Spodosols. The landscapes were marked with *Casuarina sumatrana* and *Zoysia matrala* that produce acid humus, mean annual temperature of 32^{o}C, and high rainfall (up to 3500 mm/year) with 3 ridges (at most ±5 m.a.s.l) and swales formed by the eustatic sea effect. The ridges area stated in the order of: 1) the youngest ridge, 2) the intermediate ridge, and 3) the innermost ridge. Entisols (Baging Series) found in ridge 1, while in ridge 2 (profile P1 and P2), spodic horizon samples dates 3000 year-old, and 6000 year-old in ridge 3 (profile P3). Rusila Series is often flooded, thus classification is difficult.

Soil samples were collected in two different methods, i)soil samples collected based on depth of 0-15, 15-30, 30-45 and 45-60 cm were used to study the soil suitability for crop production and ii) three Spodosols soils pits (profile P1, P2 and P3) were described based on genetic horizon their organic acids were studied to clarify the formation of spodic horizon. All of the samples were subjected to pyhsico-chemical analyses. BRIS soils are sandy (>95% sand) mainly single grain, high net leaching (>12 cm/hour), pH (4-5), C_{org} (0.2-2.0%), CEC <5 $cmol_c/kg$, low EC, high bulk density (1.65 g/cm^3) and low water content (<10 vol.%). Mineralogical study showed quartz dominance with traces of feldspar, mica, gibbsite, hematite, halloysite and anatase that indicate intense weathering and/or leaching have taken place in the plains.

Organic acids functional group (by FTIR spectroscopy) and their content (by humic acid analyses) were determined, and the data showed dominance of sharp and strong C-O group complexes and –COOH group (2000 – 3000 cm^{-1}) of carboxylic groups that known to corrode quartz, thus soil losses Si and may gain Fe and/or Al in the soil profiles, with ^{13}C NMR spectra further confirms the findings. Oxalic acid (6 µM) and citric acid (12 µM) were dominant with traces of other LMW organic acids in the spodic horizon. These acids has strong affinity to form metal complexes with Fe and/or Al. Carboxylic acid groups occurs naturally in plant and animals; hence this corresponds to the presence and decomposition of Recent and Sub-recent marine deposits in the BRIS landscape. In thousands of years, carboxylic acids form organometal-chelates with Fe and/or Al metals, and transport the sesquioxides to subsoil-B horizon, accumulate and undergo periodic desiccation and precipitation, giving rise to spodic horizon.

Besides that, low ODOE (0.01-0.03) value and variations in Al_p+Fe_p ratios indicate leaching and translocation of SOM through eluvial horizon was extensive and continuous. Al_o + 1/2Fe_o ratio in the entire spodic horizon were ≥ 0.5, indicative of sesquioxides accumulation in the profiles, and therefore, all the profile have Bs horizon. However, C/Me ratio of <15 is typical for soils with strong humus illuviation (Bhs horizon). This was only observed for profile P3 (6000 years-old age). The strength of the cementation corresponds directly to the age of the podzols; the time of podzolization process with profile P1 and P2 (3000 years-old age) < profile P3 which is strongly cemented.

BRIS soils have inherent low fertility, and despite the limitations, the Bs and/or Bhs horizon show high C_{org} (up to 3%) and C:N ratio (±25) show possibility of crop production. And, Al toxicity is not a problem in BRIS soils. For national interest, Wong (2009) soil-crop suitability assessments were conducted and BRIS soils are marginally suitable for crop production prior soil improvement, especially Rudua and Rusila Series.

The *fulvate theory* and *LMW theory* may fit the podzolization process in the tropics with some shift in the theory, whereby the so called *"initiation processes"* were not observed and with some variations in the subsequent processes. Spodosols in the study area were mainly influenced by acid humus, desilification process, vertical/horizontal water movement, periodic physical desiccation and organo-metal complexes chemical precipitation, therefore, the sandy Spodosols of the Kelantan-Terengganu Plains are indeed unique and special. The study has clarified the occurrence, properties and productivity of soils in the sandy beach ridges (BRIS) soils with special attention to the sandy Spodosols; therefore, the objectives of the study have been achieved.

Abstrak thesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

TABURAN, SIFAT FIZIK-KIMIA DAN KESESUAIAN TANAH PASIR PANTAI (BRIS) DI SEKITAR PESISIR PANTAI KELANTAN-TERENGGANU, SEMENANJUNG MALAYSIA

oleh

ROSLAN BIN ISMAIL

Januari 2012

Pengerusi : Prof. Shamshuddin Jusop, PhD

Fakulti : Pertanian

Suatu kajian telah dijalankan untuk memahami kewujudan, sifat fizik-kimia dan produktiviti tanah pesisir pantai Kelantan-Terengganu pantai timur Semenanjung Malaysia. Ia terdiri dari Siri Baging, Rusila, Rhu Tapai (profil P1), Rudua (profil P2) dan Jambu (profil P3). Tiga profil yang tersebut mempunyai horizon spodik dan dikelaskan sebagai Spodosols. Landskapnya ditumbuhi rumput (*Zoysia matrala*) dan *Casuarina sumatrana* yang menghasilkan humus asid, min suhu tinggi (± 32^{o}C) dan taburan hujan tinggi (±3500 mm/tahun). Ia terdiri dari 3 permatang pasir (±5 m.a.s.l) dan paya (di antara permatang pasir) iaitu: 1) permatang pasir muda, 2)permatang pasir pertengahan dan 3) permatang pasir tua. Permatang pasir 1 biasanya Entisols (Siri Baging), Spodosols wujud di permatang pasir 2 (profile P1 dan P2) dengan horizon spodik bertarikh 3000 tahun dan 6000 tahun di permatang pasir 3 (profile P3). Siri Rusila kerap ditenggelami air, menyukarkan kerja pensampelan tanah dan kalsifikasinya.

Dalam kajian ini, sampel tanah diambil melalui dua kaedah, i) tanah diambil berdasarkan kedalaman 0-15, 15-30, 30-45 dan 45-60 sm untuk kajian kesesuain tanaman dan ii) tiga profil tanah Spodosols (profil P1, P2 dan P3) digali, disampel dan dilabel berdasarkan horizon genetiknya untuk kajian lanjut mengenai asid organik dan pembentukan horizon spodik. Kesemua sampel tanah dianalisa untuk sifat fizik-kimia tanah. Tanah BRIS mempunyai >95% kandungan pasir, larutlesap sangat tinggi (>12sm/jam), pH (4-5), karbon organik (0.2-2.0%), KPK < 5 $cmol_c/kg$, rendah konduktiviti elektrik, ketumpatan pukal yang tinggi (±1.65 g/cm^3) dan rendah kandungan air tanah (<10 vol.%). Kajian mineralogi menunjukkan dominasi kuartza dan sedikit mineral feldspar, mika, gibsit, hematite, hallosit dan anatas yang membuktikan kesan luluhawa dan larut lesap yang sangat tinggi.

Jenis asid organik (analisa FTIR) dan kandungannya (analisa asid humik) dalam sampel tanah ditentukan. Data FTIR menunujukkan kehadiran kumpulan berfungsi asid karboksilik C-O dan –COOH (2000 – 3000 sm^{-1}) dalam horizon spodik dan analisa ^{13}C NMR turut mengesahkan kehadiran kumpulan tersebut. Asid organik molekul rendah turut hadir, didominasi oleh asdi sitrik (12 µM) dan oksalik (6 µM). Asid karboksilik yang hadir secara semulajadi dalam tumbuhan dan haiwan. Asid tersebut menghakis kuartza dan melepaskannya Fe/Al ke dalam profil tanah. Justeru, ia membentuk mendapan kompleks organo-logam dengan Fe dan/atau Al. Selepas ribuan tahun proses luluhawa, mendapan tersebut menjadi horizon spodik.

Dsamping itu, nilai ODOE yang rendah (0.01-0.03) dan perbezaan nilai Al_p+Fe_p membuktikan proses larutlesap yang berterusan dan tinggi telah memindahkan bahan organik melalui zon eluviasi. Nilai $Al_o + 1/2Fe_o \geq 0.5$ dalam horizon spodik membuktikan kewujudan lapisan seskuioksida (Bs) dalam tanah Spodosol. Manakala, nilai C/Me < 15 menunjukkan kewujudan lapisan iluvasi-

humus (Bhs) wujud hanya dalam profil P3 berusia 6000 tahun. Kekerasan horizon spodik berkadar terus dengan usia tanah tersebut, di mana profil P1 dan P2 (bertarikh 3000 tahun) sedikit keras berbanding profil P3 yang sangat keras.

Tanah BRIS mempunyai kesuburan yang sangat rendah, namun horizon Bs dan Bhs. Namun begitu, nilai karbon organik (±3%), nilai C:N (20-30) dan keasidan medium tanah menunjukkan potensi untuk pertanian. Horizon spodik di tanah BRIS tidak mengalami ketoksikan Al. Penilaian kesesuaian tanah-tanaman berdasarkan Wong (2009) ke atas tanah BRIS mendapati Siri Rudua dan Rusila mempunyai kesesuaian terhad untuk pertanian tanaman sebelum pembaikpulihan tanah dilakukan.

Melalui kajian ini, didapati teori fulvat dan teori LMW boleh diadaptasikan untuk proses podzolisasi di kawasan tropika dengan sedikit perubahan dalam teori tersebut. Ini kerana tiada proses *'initiation'* dan proses seterusnya sedikit berbeza di kawasan tropika berbanding kawasan iklim sejuk. Horizon spodik kawasan pesisir pantai tropika tidak depengaruhi faktor tumbuhan dan tiada perubahan iklim yang ketara. Spodosol di kawasan kajian khususnya dipengaruhi oleh pembebasan asid humus, proses desilifikasi, pergerakan air melalui profil tanah, proses pengeringan berperingkat tanah dan pembentukan mendapan kimia melalui kompleks organo-logam oleh asid organik. Ini menjadikan Spodosol pasir adalah khusus dan unik bagi kawasan permatang pasir, iaitu kawasan kajian. Kajian ini telah menjelaskan kewujudan, sifat fizik-kimia dan produktivit tanah permatang pasir (BRIS) dengan pendekatan khusus kepada Spodosol berpasir, maka objektif kajian telah di capai.

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Last but not least, thank you to the lab assistant and staff at the Faculty of Agriculture, UPM in giving a helping hand in making the analyses possible and in timely manner. In future, I hope to contribute to the university and the development of the country especially in the land resource management field.

I certify that a Thesis Examination Committee has met on 26 January 2012 to conduct the final examination of Roslan bin Ismail on his thesis entitled "Occurrence, Properties and Suitability of Sandy Beach Ridges (BRIS) Soils in the Kelantan-Terengganu Plains, Peninsular Malaysia" in accordance with the Universities and University College 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 Doctor of Philosophy.

Members of the Examination Comittee were as follows:

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Date: 23 April 2012

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of **Doctor of Philosophy**. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently submitted for any other degree at Universiti Putra Malaysia or any other institution.

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ROSLAN BIN ISMAIL

Date: 26 January 2012

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LIST OF ABBREVIATIONS

BRIS – beach ridges interspersed with swales

DOA- Department of Agriculture

LMW- low molecular weight

HMW- high molecular weight

MARDI- Malaysia Agriculture Research and Development Institute

NKTB- National Kenaf and Tobacco Board

SOM- soil organic matter

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