UNIVERSITI PUTRA MALAYSIA

SELECTED PHYSICO-CHEMICAL AND BIOLOGICAL PROPERTIES OF SOILS IN DIFFERENT FARMING SYSTEMS

ABRAR SALEH MAQTAN BA QATYAN

FS 2021 3

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By

ABRAR SALEH MAQTAN BA QATYAN

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

December 2019

DEDICATION

My father

My mother

My sister, my brother and their sons

And

My husband Khairallah Ahmed Al-Hushbi

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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December 2019

Chairman : Hishamuddin bin Omar, PhD
Faculty : Science

Climate change, loss of fertile top soil, unsustainable agriculture practices and excessive use of agrochemicals lead to soil depletion, loss of agriculture land and threat to food security. These problems cannot be ignored and sustainable solutions must be found to ensure human existence. In the past, the agronomist and soil scientist devoted primarily on soil physical and chemical properties to address some of those issues. Recently, the issues of soil health are beginning to be taken seriously. Therefore, the objectives of the present study are to characterize the physical and chemical properties of different agriculture land (CEFS, Papaya, Organic and Nilai farm), documenting the soil invertebrates, bacteria and fungi population in those areas. Three composite soil samples were collected from each site, followed by the physical and chemical analysis. The physical properties assessed include soil texture, bulk density, moisture, temperature, and soil porosity. The soil chemical properties were pH, EC, total C&N, C/N, extractable P, Ca, Mg, K, Na, organic matter, and effective CEC. Pitfall traps and Tullgren funnel were used for sampling soil invertebrates. Invertebrates were preserved in 70% ethanol and identified using soil invertebrate morphological classification. The fungi and bacteria were isolated using soil dilution technique and soil plate technique on RBA, PDA and NA. Morphological characteristics of the bacteria and fungi were identified. In addition, API20E biochemical test kit was used to identify bacteria to genus level. The physical and chemical properties of soil showed some variation in each location. CEFS, Papaya and Organic farm in UPM campus have Serdang soil series while Nilai agriculture field has Rengam series. Bulk density ranged between 1.07-1.35 g/cm^3, porosity (54.67-65.00), temperature (33.66-38.00 ^0C), moisture (18.57-32.85%), clay (21.57-39.46%), silt (5.78-22.29%), sand (33.27-56.86) and soil texture class ranged from clay, sandy clay to sandy-clay-loam. Macrofauna were dominant in Papaya and CEFS comprising of about 80% fauna found. Mesofauna comprised of 43.22% in Organic farm, while microfauna composed only 2.85% in Organic farm. The ecosystem engineers comprised of 39.56% in Papaya farm. Litters transformers were highest in CEFS comprising of 54.05% and predatory fauna were highest in Nilai farm comprising of 46.29%. The most common bacteria in all farms were Coccobacillus (31.10%), Bacilli

G- comprising (26.91%) in CEFS, Papaya and Organic farm, and Actinobacteria comprising (15.86%) in CEFS, Papaya and Nilai farm respectively. *Aspergillus*, *Penicillium* and *Trichoderma* were the most common fungi in all farms and Ascomycota being the most dominant fungal division comprising of 79.03%. The highest diversity of soil fauna and flora were in Organic farm and CEFS. The overall scores approach enabled the soils to be assessed simultaneously for physical, chemical, invertebrates, bacterial and fungal aspect. It was found that CEFS and Organic farm were superior in overall aspect. This study concluded that undisturbed and organic farm have better overall soil properties than varying level of disturbed soil. The rank and score approach enable the soil with multiple parameter assessment such as physical, chemical, and biological properties to be compared simultaneously.

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

SIFAT FIZIKAL-KIMIA DAN BIOLOGI TANAH DI KAWASAN YANG BERBEZA DARI SEGI SISTEM PERTANIAN

Oleh

ABRAR SALEH MAQTAN BA QATYAN

Disember 2019

Pengerusi : Hishamuddin bin Omar, PhD
Fakulti : Sains

Perubahan iklim, ketandusan tanah, kegiatan pertanian yang tidak efisien serta penggunaan agrokimia yang berlebihan boleh mengakibatkan kemorosotan kualiti tanah dan menjejaskan penghasilan makanan. Masalah tersebut tidak boleh diabaikan begitu sahaja dan penyelesaian yang efektif perlu dipraktikkan bagi menjamin kesejahteraan hidup manusia. Bagi menangani isu-isu tersebut, ahli sains tanah dan agronomist telah mengkaji sifat fizikal dan kimia tanah secara terperinci. Bagaimanapun kebelakangan ini, masalah kesuburan tanah amat membimbangkan. Oleh itu, objektif kajian ini adalah untuk mengenal pasti sifat fizikal dan kimia tanah di kebun pertanian yang berbeza (CEFS, Ladang betik, Ladang organik dan Ladang Nilai) serta mendokumentasi populasi invertebrata tanah, bakteria dan kulat di kawasan tersebut. Tiga sampel tanah komposit telah dikumpul dari setiap kawasan dan dianalisis dari segi fizikal dan kimia. Sifat fizikal tanah yang dinilai merangkumi tekstur, ketumpatan, kelembapan, suhu dan koranggaan tanah. Sifat kimia tanah yang dinilai adalah pH, EC, jumlah C & N, C/N, P, Ca, Mg, K, Na yang boleh diekstrak, bahan organik dan CEC. Perangkap Pitfall dan corong Tullgren telah digunakan untuk persampelan invertebrata tanah. Invertebrata tanah disimpan dalam 70% etanol dan dikenalpasti mengikut ciri-ciri morfologi mereka. Pemencilan kulat dan bakteria telah dilaksanakan melalui teknik larutan tanah dan teknik plat tanah pada RBA, PDA dan NA. Ciri-ciri morfologi bakteria juga telah dikenalpasti. Selain itu, kit ujian biokimia API20E digunakan untuk mengenal pasti genus bakteria. Sifat fizikal dan kimia tanah menunjukkan beberapa variasi di setiap lokasi. Ladang CEFS, Ladang betik dan Ladang organik di kampus UPM mempunyai siri tanah Serdang manakala Ladang Nilai mempunyai siri tanah Rengam. Ketumpatan tanah mempunyai nilai antara 1.07-1.35 g/cm^3, keronggaan tanah (54.67-65.00), suhu (33.66-38.00^{0}C), kelembapan (18.57-32.85%), tanah liat (21.57-39.46%), kelodak (5.78-22.29%), pasir (33.27-56.86) dan klasifikasi tekstur tanah merangkumi tanah liat, tanah liat berpasir dan tanah liat berpasir. Kategori makrofauna adalah dominan di Ladang betik dan CEFS di mana ia terdiri daripada 80% fauna yang dijumpai. Ladang Organik merekodkan kategori mesofauna sebanyak 43.22% manakala mikrofauna hanya sebanyak 2.85% sahaja. Kategori penjana ekosistem terdiri daripada 39.56% di Ladang betik. Agen penguraian mencatat nilai tertinggi di CEFS iaitu 54.05% dan fauna pemangsa mencatat nilai tertinggi di Ladang Nilai iaitu 46.29%. Coccobacillus merupakan bakteria yang paling kerap dijumpai di semua lokasi (31.10%), di mana Bacilli G- mencatat 26.91% di CEFS, Ladang betik dan Ladang organik, manakala Actinobacteria mencatat nilai 15.85% di CEFS, Ladang betik dan Ladang Nilai. *Aspergillus*, *Penicillium* dan *Trichoderma* adalah kulat yang paling kerap dijumpai semua lokasi di mana Ascomycota merupakan kategori kulat yang paling dominan dengan nilai 79.03%. Kepelbagaian fauna tanah dan flora yang paling tinggi adalah di Ladang organik dan CEFS. Teknik penskoran secara keseluruhan membolehkan tanah dinilai secara serentak dari segi fizikal, kimia, invertebrata, bakteria dan kulat. Kajian mendapati CEFS dan Ladang organik mencatat skor yang terbaik bagi setiap aspek yang dinilai. Kesimpulannya, Ladang organik yang tidak terganggu mempunyai sifat tanah yang paling ideal berbanding tanah di lokasi terganggu yang lain. Pendekatan mengikut aras nilai dan skor membolehkan tanah dinilai secara serentak dari segi fizikal, kimia dan biologi.

ACKNOWLEDGEMENTS

In the beginning thanks to Allah for helping me all over this work.

I cannot find words to express my feeling towards my supervisor Dr. Hishamuddin Omar, for his great help and guidance in producing this thesis.

I would like to express my sincere thanks to the members of my supervisory committee: Assoc. Prof. Muskhazli Mustafa, Dr. Nur Ain Izzati for all helpful suggestions which contributed to the many aspects of this study and improved the quality of this thesis.

I would like to acknowledge all the lecturers and staff in Faculty of Science Department of Biology UPM who taught me all the things which help me to conduct this study.
I would like to thank the UPM staff at the Department of Land Management, UPM for their help in soil analysis.

I would like to thank Putra grant to support this research which was funded by code project: GP/2017/9568000 of UPM Malaysia.

My sincere gratefulness to my friends in Yemen and Malaysia and all the lecturers and staff in Faculty of Education and Science Department of Biology in University of Aden, Yemen, with special thanks for Prof. Dr. Abdul Nasser Al-Gifri Professor of Taxonomy of Flowering Plants Dept. of Biology, University of Aden, for encouragement and helping me in all things during the study.

Finally, no thanks can repay for my family and my husband their great help, patience, and encouragement, for cordial and moral support, to present this work.

This thesis was submitted to the Senate of the 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:

Hishamuddin bin Omar, PhD
Senior Lecturer
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Muskhazli bin Mustafa, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

Nur Ain Izzati binti Mohd Zainudin, PhD
Associate. Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 12 August 2021

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LIST OF ABBREVIATIONS

API 20E	Analytical Profile Index Enterobacteriaceae
BMP	Best Management Practice
CCD	Convention on Desertification
CEC	Cation exchange capacity
EC	Electrical conductivity
FAO	Food and Agriculture Organization
FCCC	Framework Convention on Climate Change
GAP	Development Good Agricultural Practice
GSBI	Global Soil Biodiversity Initiative
GSP	Global Soil Partnership
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
ITPS	Intergovernmental Technical Panel on Soils
NGO	Non-governmental organization
PDA	Potato Dextrose Agar
RBA	Rose Bengal agar
SDGs	sustainable development goals
SOC	soil organic C
SOM	Soil organic matter
UN	United Nations.
WSBI	World Soil Biodiversity Assessment

CHAPTER 1

INTRODUCTION

Soil is a vital resource that provides food, fuel, and fiber. It forms the basis of food security and environmental quality, both essential for mankind. The necessity of soil to human well-being is often not realized until the food production drops or when the risk of being eroded or degraded to the level until it loses its resilience (Blanco and Lal., 2008). Bearing that in mind, presently mother earth is under serious threats from multiple fronts such as climate change, unsustainable agriculture practices, intensification of human activities, human population increase and spread of diseases, all of them are the most fundamental issues affecting the soil in Malaysia (Murad et al., 2008; Hassan, 2015).

Furthermore, a lack of agricultural land is already facing negative effects on global food production (Turbe et al., 2010; Cardoso et al., 2013; Orgiazzi et al., 2016; Oldeman et al., 2017). Just as ecosystem services are influenced by (bundles of) soil processes, the latter are in turn affected by the soil threats. Recently the problems pertaining to soil have been highlighted (Cardoso et al., 2013; Orgiazzi et al., 2016; Bünemann et al., 2018).

Therefore, there is an urgent need to promote awareness on the key soil issues and their importance to mankind. This is necessary to maintain and improve global soil resources by limiting the agricultural practices such as tillage, fertilization management, and farm management for food, fiber, and water production. The efforts should take into account the sustainability of energy, climate change, conservation of biodiversity and comprehensive protection of the ecosystem under all previous threats. Such issues must be recognized and shedding light on them which is known as the security of soil (McBratney et al., 2014).

In past studies, soil status assessment was limited to focus primarily on the chemical and physical properties of soil to reflect the soil quality. However, in the presence of multiple threats facing the soil, there is a need for a broader understanding and evaluation to include all components of soil. In addition, the understanding of biological sensitive indicators should be able to provide an early warning against any threat to the soil. Unfortunately, present studies on the soil biological aspect were inadequate (Bünemann et al., 2018) even though they show great potential for a course in the ecosystem (Bünemann et al., 2018). The impact of unmanaged use of agrochemicals to the soil biological component is still unknown. Moreover, most of the agricultural institution has no provision to study the biological aspect of soil (Turbe et al., 2010; Cardoso et al., 2013).

The diversity of life in the soil, also known as soil biodiversity is an important but presently is an incomprehensible aspect of the terrestrial ecosystems. Soil biodiversity consists of organisms that spend whole or part of their life cycle in the soil or on the immediate surface (including surface litter and decomposing logs). Therefore, better understanding on the importance and contribution of soil biodiversity for the resistance and resilience against the stress and disturbed is crucial. Since much of the soil organisms are poorly known, the relations between soil biodiversity and the performance of ecosystems is not clear presently (Chapin et al., 2000; Brussaard et al., 2004). Limited studies on this subject suggested that biodiversity affects the ecosystem stability, productivity, and resilience to stress and disturbance (Torsvik and Ovreås, 2002; Cardoso et al., 2013; Bünemann et al., 2018).

Rapid land-use change such as urbanization, agriculture, deforestation, and desertification can have a multiplier effect on the soil and soil biodiversity that could extend beyond the original location of the disturbance (Wall et al., 2015). A good example of that is climate change. Another important reason for the study of microbial diversity is the lack of sufficient knowledge about the microbes presently and in the past. There is no consensus on how many species exist in the world, and the potential of most species of interest, or the rate at which they disappear or emerge (Fakruddin and Mannan, 2013).

Hopefully, the presents will provide new information about soil communities diversity in four different locations in University Putra Malaysia and Nilai, Negeri Sembilan that have different soil properties, vegetation and agricultural activities that directly or indirectly influenced ecosystems. Both of them create some benefits and at the same time, some impacts and tradeoffs.

The impact of these activates on the soil biota community's diversity and abundance is studied and analyzed. The pertinent questions to be asked are (a) how bacteria, fungal and invertebrates diversity, abundance and composition changed due to soil management and human activities, (b) if the relationship exist, what is the impact of soil properties to soil bacteria, fungal and invertebrates diversity.

To answer those questions, we assumed two hypotheses: (i) soil bacteria, fungal and invertebrates' diversity and soil properties are affected by soil management, human and agriculture activities; (ii) the soil properties exert influence to soil bacterial, fungal and invertebrates' diversity.

1.1 Objectives

The objectives of the study were outlined as follows:

1.1.1 General objective

To determine the flora and fauna diversity in the sites with different soil properties (within the study area)

1.1.2 Specific objectives

1- To determine the physicochemical soils properties in different farm practices.

2- To evaluate the soils faunal diversity in different farm practices.

3- To evaluate the soils bacteria diversity in different farm practices.

4- To evaluate the soils fungal diversity in different farm practices.

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