UNIVERSITI PUTRA MALAYSIA

INFLUENCE OF ORGANIC MATTER ON SOIL AGGREGATION AND ERODIBILITY OF SOME MALAYSIAN SOILS

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INFLUENCE OF ORGANIC MATTER ON SOIL AGGREGATION AND ERODIBILITY OF SOME MALAYSIAN SOILS

By

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Thesis Submitted in Fulfilment of the Requirements for the Degree of Master of Agricultural Science in the Faculty of Agriculture, Universiti Pertanian Malaysia

May 1992

" Dedicated To My Brother Long Buang "

ACKNOWLEDGMENTS

Foremost, I wish to express my appreciation and sincere gratitude to Asso. Prof. Dr. Hj. Mohd. Mokhtaruddin Abd. Manan, Chairman of the committee, for his constant guidance, assistance and advice during the course of this study and also for his valuable suggestions and comments in the preparation of the text. Thanks are also due to the members of the committee, Asso. Prof. Dr. Hj. Wan Sulaiman Wan Harun and Dr. Norhayati Moris for their constructive criticism, advise and help.

The financial support received from Regional Center for Graduate Study and Research in Agriculture (SEARCA) and the Bank Pertanian Malaysia is gratefully acknowledged.

My thanks also go to the members of the Laboratories of Soil Science Department, Universiti Pertanian Malaysia and Soils and Crop Management Division, Rubber Research Institute of Malaysia for their cooperation and to all my friends who helped me in one way or another.

My appreciation goes to my mother, my wife Rohaida, my children Mohd. Shazreen and Nur Syareena and my brother Long Buang whose love and understanding always been my source of inspiration and encouragement.

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Abstract of thesis submitted to the Senate of Universiti Pertanian Malaysia in fulfilment of the requirements for the degree of Master of Agricultural Science.

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Chairman : Asso. Prof. Dr. Hj. Mohd. Mokhtaruddin Abd. Manan

Faculty : Agriculture

The dominant role of organic matter in promoting aggregate stability and the strong relationship between the latter and soil erodibility are observed consistently by many researchers. These findings suggest that, organic matter and soil erodibility should have a strong relationship too. However, this is not always true. Some workers found a weak relationship between the two. With this background, experiments were conducted to examine the role of organic matter and its constituents on soil aggregation and erodibility for some Malaysian soils.

Ten soils comprising of five soil series under different landuses and varying organic matter contents were subjected, *in situ*, to simulated rain. The soil losses were taken as their relative erodibility values. The aggregation characteristics

indices, namely, percent aggregation, mean weight diameter after dry sieving (MWD_d), mean weight diameter after wet sieving (MWD_w), percent water-stable aggregates >0.5mm (%WSA >0.5), stability index (SI), clay ratio and T20/T2 of the soils were determined. T_2 and T_{20} are percentage of light absorption after the soil being dispersed in water for two and twenty minutes respectively. MWD_w, %WSA > 0.5 and SI are taken as macroaggregate stability and clay ratio and T20/T2 as microaggregate stability. The soils were also analysed for total organic matter content, decomposed organic matter (humus) and constituents of organic matter (fulvic acid, humic acid and polysaccharide). The sum of fulvic acid, humic acid and polysaccharide is referred to as humus.

It was found that, humus acted as a more effective binding agent and consequently showed a better relationship with soil erodibility compared to the total organic matter. This implies that the forms of organic matter are more important than its total amount in relation to soil aggregation and erodibility.

Malaysian soils tend to have a greater amount of fulvic acid than humic acid and polysaccharide. Their relative importance with respect to soil aggregation and soil erodibility is in the order of fulvic acid > polysaccharide > humic acid.

Aggregate size distribution and aggregate stability are significantly correlated to soil erodibility. However the macroaggregate stability had a more dominant effect than the microaggregate stability. Of the macroaggregate stability indices tested, %WSA >0.5 was found the most efficient index for soil erodibility.

Landuse types which cause differences in organic matter status of the soils directly affect the aggregation characteristics and hence soil erodibility value. The results showed, erodibility values of a same soil series subjected to different landuses were different.

Abstrak tesis yang dikemukakan kepada Senat Universiti Pertanian Malaysia sebagai memenuhi syarat keperluan untuk mendapatkan Ijazah Master Sains Pertanian.

PENGARUH BAHAN ORGANIK KE ATAS PENGAGREGATAN DAN ERODIBILITI TANAH BAGI BEBERAPA SIRI TANAH DI MALAYSIA

Oleh

TAJUDDIN BIN ADAN

Mei 1992

Pengerusi : Prof. Madya Dr. Hj. Mohd. Mokhtaruddin Abd. Manan

Fakulti : Pertanian

Peranan bahan organik yang dominan dalam meningkatkan kestabilan agregat dan hubungan yang kuat di antara kestabilan agregat dan erodibiliti tanah adalah pendapat yang telah diterima umum. Maklumat ini mencadangkan, bahan organik dan erodibiliti semestinya mempunyai hubungan yang kuat juga. Walau bagaimanapun sesetengah kajian mendapati hubungan yang lemah di antara keduanya. Berdasarkan kepada latar belakang ini, eksperimen dijalankan untuk mengkaji pengaruh bahan organik dan juzuk-juzuknya terhadap pengagregatan dan erodibiliti tanah bagi beberapa siri tanah di Malaysia.

Sepuluh jenis tanah yang terdiri daripada lima siri dengan pelbagai gunatanah dan kandungan bahan organik yang berbeza, *in situ*, diperlakukan dengan hujan tiruan. Jumlah tanah yang

terhakis diambilkira sebagai nilai relatif erodibiliti tanah. Penunjuk-penunjuk sifat pengagregatan tanah iaitu; peratus pengagregatan, berat garispusat purata selepas ayakan kering (MWD_d), berat garispusat purata ayakan basah (MWD_w), peratus agregat stabil-air >0.5 mm (%WSA >0.5), indek kestabilan (SI), nisbah liat dan T20/T2 bagi tanah-tanah tersebut ditentukan. MWD_w, %WSA >0.5 dan SI menunjukkan kestabilan agregat makro sementara nisbah liat dan T20/T2 menunjukkan kestabilan agregat mikro. Kandungan keseluruhan bahan organik, bahan organik terurai sepenuhnya (humus) dan juzuk-juzuk bahan organik (asid fulvik, asid humik dan polisakarida) tanah juga ditentukan. Jumlah asid fulvik, asid humik dan polisakarida diambilkira sebagai humus.

Kajian mendapati, bahan organik yang telah terurai sepenuhnya (humus) bertindak sebagai ajen pengikat yang lebih efektif dan seterusnya menunjukkan hubungan yang lebih baik dengan erodibiliti berbanding bahan organik keseluruhannya. Ini menunjukkan, bentuk bahan organik adalah lebih penting daripada jumlah keseluruhannya dalam hubungan dengan pengagregatan dan erodibiliti tanah.

Tanah di Malaysia mengandungi lebih asid fulvik berbanding dengan asid humik dan polisakarida. Susunan kepentingan juzuk bahan organik terhadap pengagregatan dan erodibiliti tanah ialah asid fulvik > polisakarida > asid humik.

Taburan saiz agregat dan kestabilan agregat, kesemuanya mempengaruhi erodibiliti. Walau bagaimanapun pengaruh kestabilan agregat makro adalah lebih dominan berbanding kestabilan agregat mikro. %WSA >0.5 didapati merupakan indeks yang paling sesuai untuk erodibiliti tanah daripada tiga penunjuk kestabilan agregat makro yang diuji.

Gunatanah yang berlainan menyebabkan perbezaan kandungan bahan organik yang secara terus mempengaruhi sifat pengagregatan dan erodibiliti tanah. Hasil kajian menunjukkan, nilai erodibiliti bagi tanah yang sama tapi gunatanahnya berlainan adalah berbeza-beza.

CHAPTER I

INTRODUCTION

Agricultural expansion in Malaysia is at present shifting to marginal areas, notably the uplands and steeply sloping areas, because most of the lowlands suitable for agriculture have already been developed. These areas are highly vulnerable to soil erosion. The high rain erosivity (Dale, 1960 and Nieuwolt, 1981) enhances the severity of the soil erosion problem. Erosion control is indispensable in the development of steepland for agriculture because excessive soil loss can lead to soil structure deterioration, organic matter and nutrient depletion, decrease in soil fertility and hence reduced crop yield (Lal, 1976; 1984; 1988). Therefore, soil properties particularly erodibility and those directly affecting it need to be investigated. Data on soil erodibility are important for soil conservation planning programme. They are needed for formulating appropriate soil and crop management systems for steepland cultivation. For this reason, soil erodibility assessment of these soils is very essential.

Soil erodibility can be determined by three approaches as categorised by El-Swaify and Dangler (1977). The first approach is based on actual measurements of soil loss from standard bare plot (Wischmeier, 1976). The second method is based on measurements under simulated rainfall and the third, estimation using predictive equation or nomograph. The first two methods, particularly the actual measurements from bare plots, are costly and time consuming.

Because it is simple, rapid and cheap, the third approach is often used, using the model described by Wischmeier *et al.* (1971). However, its result for Malaysian soils is not consistent. Maene and Wan Sulaiman (1980) and Wan Sulaiman *et al.* (1981) reported large differences between soil erodibility value measured from standard erosion plots and those estimated using the nomograph of Wischmeier. It seems that a separate equation needs to be derived for more reliable estimates on the tropical soils of Malaysia. To do so, factors contributing to the erodibility of the soil should be fully understood. There are various factors affecting erodibility such as density, porosity, permeability, aggregation, texture, clay mineralogy, sesquioxides and organic matter contents. Texture, clay, sesquioxides and organic matter indirectly affect erodibility by influencing soil aggregation which in turn influence soil density, porosity, pore size distribution and permeability. In this thesis, only the effect of organic matter on soil aggregation and erodibility will be considered.

The role of organic matter in promoting soil aggregation is widely recognised. However, not all the organic matter present is active in the process of aggregate formation. It has been reported that the decomposed products are more important than the undecomposed and partly decomposed products (Allison, 1973 and Soong, 1980). In addition, the constituents of the decomposed products may also influence soil aggregation as discovered by many workers (Tisdall and Oades, 1982 ; Chaney and Swift, 1984 ; Cheshire *et al.*, 1985 and Fortun *et al.*, 1989). Nevertheless, study in this aspect for Malaysian soils is very limited.

It has also been established that there is a good relationship between soil aggregation and erodibility (Egashira *et al.*, 1983 and Elwell, 1986). This suggests that soil erodibility should be closely related to organic matter. However, there are some differences in opinion concerning the importance of organic matter in influencing soil erodibility. Sambyal and Sharma (1986) and Datta *et al.* (1990) indicated positively and highly significant relationship between organic matter and soil erodibility. On the contrary, El-Swaify and Dangler (1977) found that this was not so. In all three studies the total amount of organic matter was considered. As mentioned earlier the decomposed products and may be their constituents are more important in aggregation. This may be one of the reasons for the discrepancy observed in the soil erodibility and organic matter relationship.

Egashira *et al.* (1983) and Elwell (1986) reported a good relationship between soil erodibility and macroaggregate stability. On the other hand, Mohd. Mokhtaruddin (1986) observed that, for Malaysian soils (Ultisols and Oxisols), soils with more stable microaggregates were found to be less erodible. The above findings suggest that for Malaysian soils, the microaggregate stability and not the macroaggregate stability plays a more important role in influencing soil erodibility.

The general objective of this thesis is therefore to study the influence of organic matter and its constituents on soil aggregation and erodibility. The specific objectives are :

i. to study the relationship between soil aggregation and organic matter and its constituents,

ii. to study the relationship between soil erodibility and organic matter and its constituents and

iii. to determine the relative importance of microaggregate and macroaggregate stability in influencing soil erodibility.

In the conversion of forest area to agriculture, the period between land clearing to crop establishment is the most critical stage with regards to soil erosion (Lal, 1977). During this period, soil erosion is alarming, removing most of the topsoil rich in organic matter. The subsoil left behind usually is low in organic matter content. The results from this study will provide a better understanding on the role of organic matter on soil aggregation and erodibility of Malaysian soils. The information obtained could be utilized for planning soil conservation programme in order to achieve sustainable agriculture.

CHAPTER II

LITERATURE REVIEW

Soil Organic Matter

The Nature and Constituents of Soil Organic Matter

To understand the role of soil organic matter in soil aggregation and erodibility, it is necessary to know its origin, constituent and nature. The complete organic matter of the soil comprises living organisms as well as their undecomposed, partly decomposed and completely transformed products. Though soil organic matter is a heterogeneous mixture, it can be broadly classified into two main groups. According to Kononova (1966) the two main groups are :

i. the unaltered materials which include fresh debris and non-transformed components of older debris and

ii. the transformed products or humus, which bear no morphological or chemical resemblance to parent materials from which they were derived.

The transformed products are often referred to as humified products (Hayes and Swift, 1978) although they consist of both humic and non-humic substances. Figure 1 illustrates the various constituents of soil organic matter.

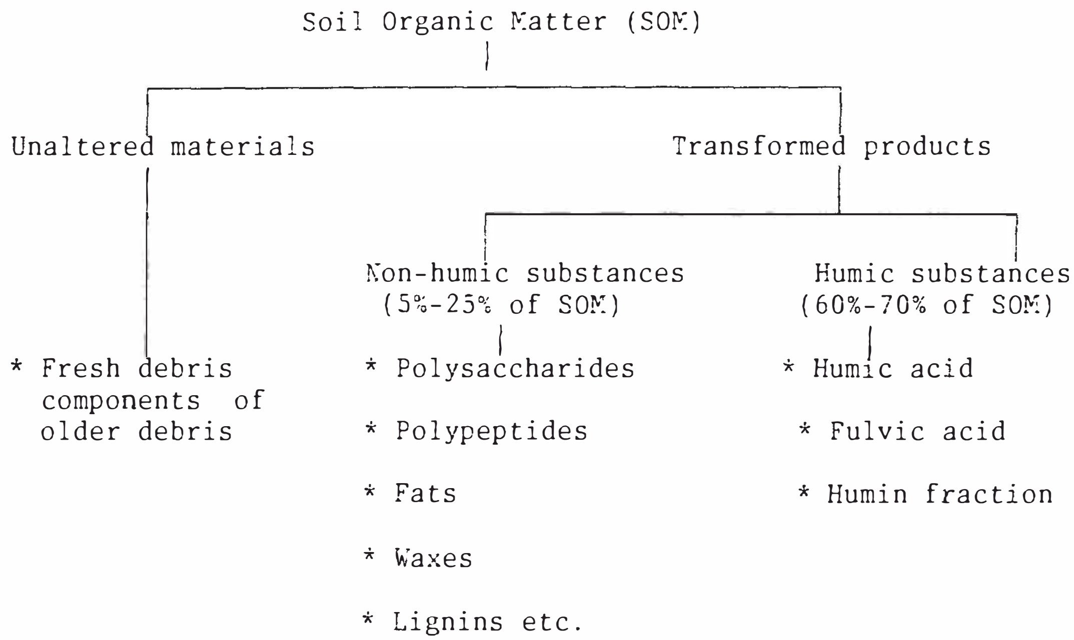

Figure 1. Schematic Illustration of the Different Constituents of Soil Organic Matter (after Norhayati Moris, 1982).

Non-Humic Substances

The non-humic substances are products of advanced decomposition of organic residues and products resynthesized by microorganisms. Collectively, these compounds of non-specific nature, form 5% to 25% of the total amount of soil organic matter (Stevenson, 1982).

Of the non-humic substances group, carbohydrates especially polysaccharide occur in greatest abundance. Other substances occur in very small quantities. Soil carbohydrates are derived from plant residues and remains of microorganisms and animals. Animals contribute a smaller proportion of soil carbohydrates and they are in the form of glycogen, snail galactin, nucleic acids and the polysaccharides containing nitrogen and sulphur (Percival, 1962).

Humic Substances

Organic substances of humic nature are in the form which cannot be related to any of the existing groups known to organic chemistry. According to Griffith and Schnitzer (1975) approximately 60% to 70% of total soil organic matter consist of humic materials, while Lau and Norhayati (1989) reported that for Malaysian soils under rubber cultivation, the humic substances constitute over 70% of soil organic matter.

The major identifiable fractions of the humic substances are humic acid and fulvic acid (Kononova, 1966; Stevenson, 1982). Humic and fulvic acids are basically organic compounds having central nuclei with side chains of aliphatic and aromatic groups such as carboxylic, hydroxylic, carbonylic and ketonic. These groups determine the complexity and in turn the reactivity of the acids. The extracted humic materials can be fractionated into several components based on their solubility in acid and alkali media. The structure of the humic fractions are similar but differ in molecular weights, content of functional groups and cation exchange capacities. Estimates of the molecular weight of the humic acid indicate a range of 50,000 to 100,000 with few molecules having molecular weight exceeding 250,000. The fulvic acid have much smaller molecule size with a range of 500 to 2000 (Stevenson, 1982).

The humic substances as well as polysaccharide have considerable influence on soil aggregation and stability. The differences between the humic fractions are summarized in Figure 2.

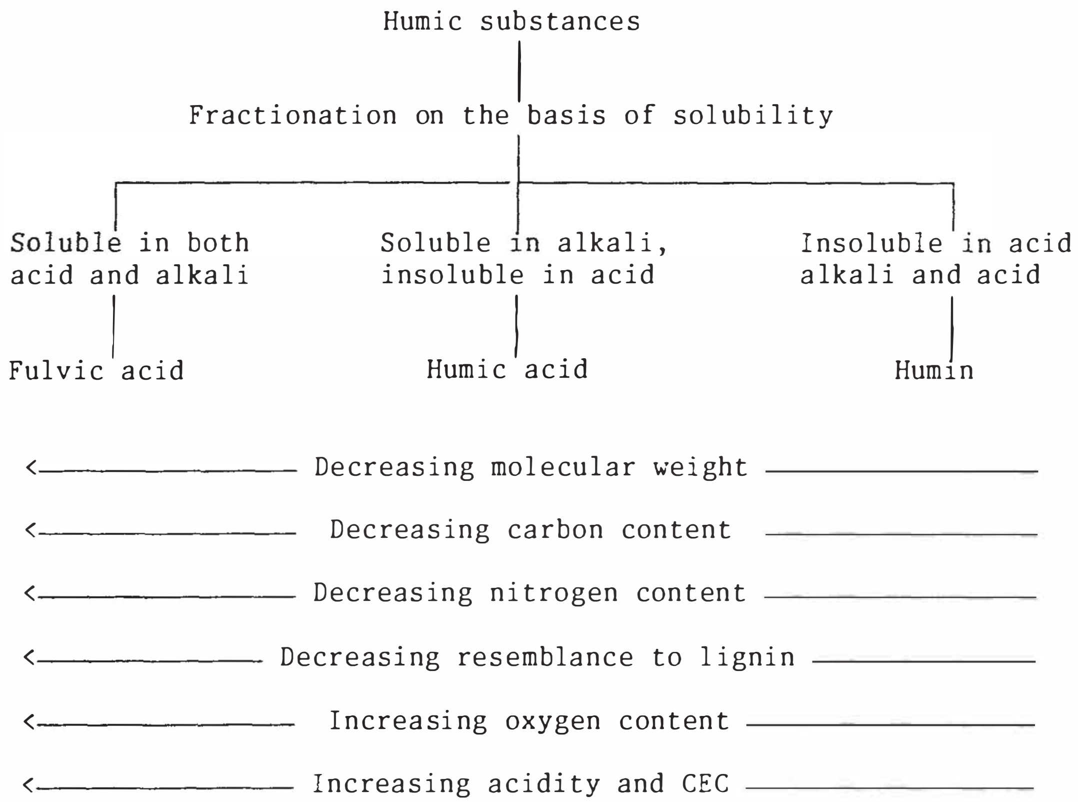

Figure 2. Classification of Humic Substances (after Hayes and Swift, 1978)