Fractal Characteristics of Soils at USM Campus

By

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ABSTRACT

Fractals are a concern new geometry to describe the variety of natural soil structures. Better understanding for the material properties can be obtained by the development in fractal geometry. A case study was carried out at the USM, Engineering Campus in Nibong Tebal, Malaysia to determine the mass fractal dimension in that area and some relationship that related to the mass fractal dimension was analyzed. Fifty soil samples were taken at various locations in USM, Engineering Campus. These soil samples were separated into two categories which are disturbed area soil samples and undisturbed area soil samples. The particle size distributions of these samples were analyzed and the mass fractal dimensions of these samples were determined. Two relationships which related to the mass fractal dimension were carried out, there were: (i) relationship between mass fractal dimension and the soil properties and (ii) relationship between mass fractal dimension and land disturbance. Four soil properties that use in the analysis were moisture content, bulk density, organic content and clay content. The results for the relationship between mass fractal dimension and soil properties were good and similar to the theory. From the analysis of the land disturbance, the mass fractal dimension for the undisturbed area was higher than the mass fractal dimension for the disturbed area.

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ABSTRAK

Serpihan ialah suatu geometri baru yang diberi perhatian dalam menjelaskan pelbagai jenis tanah asli. Pemahaman yang lebih jelas tentang ciri-ciri bahan dapat diperolehi daripada pembangunan dalam geometri serpihan. Suatu kes kajian untuk mendapatkan dimensi jisim serpihan untuk kawasan Kampus Kejuteraan, USM telah dibuat dan beberapa hubungan yang mengenainya telah dianalisis. Lima puluh sampel tanah telah dikumpul di merata tempat di Kampus Kejuruteraan, USM. Sampel tanah yang dikumpulkan ini telah dibahagikan kepada dua kumpulan, iaitu kumpulan sampel tanah untuk kawasan yang diganggu dan kumpulan sampel tanah untuk kawasan yang tidak diganggu. Taburan saiz zarah untuk sampel tanah ini dianalisis dan dimensi jisim serpihan untuk sampel tanah ini diperolehi. Dua hubungan mengenai dimensi jisim serpihan telah dianalisis, iaitu: (i) hubungan antara dimensi jisim serpihan dengan pelbagai ciri-ciri tanah dan (ii) hubungan antara dimensi jisim serpihan dengan kegangguan tanah. Empat ciri-ciri tanah yang telah digunakan dalam analisis ini adalah kandungan kelembapan, ketumpatan pukal, kandungan organik dan kandungan tanah liat. Keputusan untuk hubungan antara dimensi jisim serpihan dengan pelbagai ciri-ciri tanah adalah baik dan adalah sepadan dengan teori. Bagi analisis yang mengenai kegangguan tanah, dimensi jisim serpihan untuk kawasan yang tidak diganggu adalah lebih tinggi daripada dimensi jisim serpihan untuk kawasan yang diganggu.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Soil is a heterogeneity and complexity mixture formed by the weathering of large particles which includes both organic and inorganic mineral compounds. The weathering process includes detachment of aggregate by the raindrops and transportation by the overland flow. Larger aggregates are broken by raindrops into small aggregates and the smaller aggregates are more likely to form part of the suspended sediment in overland flow.

Fractals is a geometry to describe the special ‘scaling’ relationship for the variety of natural structures which are irregular, rough and have variety of sizes. Soil texture defined as fractal dimension is a leading indicator of soil properties and its’ functioning. The development in fractal geometry is to have a better understanding of the material properties from the natural soil. Normally, soil mass fractal dimension has been used as an index to characterize the soil degradation and characterize preferential flow patterns in field soils. In many fragmented soils studies, soil mass fractal dimension also used to identify effects of long-term management practices and in generalizing soil structure. Some fractal analysis has also indicated that fractal dimension of soil aggregates could be a useful tool to distinguish between soils and sediments of different genesis. Besides, the solid mass fractal dimension and the pore mass fractal dimensions of soils are useful as indicators of the horizon compaction status.

1.2 PROBLEM STATEMENT

Generally, characteristic of soils are determined by a variety of soil properties, such as particle size distribution, moisture content, bulk density and organic content. A soil particle size distribution is one of the fundamental soil properties in characterizing the soil. Particle size distribution is a combination of clay, silt and sand contents. The particle size distribution is widely used for the estimation of the soil hydraulic properties such as the water retention curve, saturated and unsaturated conductivities. However, one of the important developments in the study of particle size distribution is the focus on determining the fractal dimension by using the particle size distribution.

Fractals are scaling system to describe the natural soil structure. Fractal dimension of soils can be determined by using the particle size distribution of the soil, and there are also some relationship between the particle size distribution and other properties such as moisture content, bulk density and organic content. So, there is a probability of relationships between the fractal dimension and the other soil properties.

It is important to know the relationship between the fractal dimension and the soil properties because the fractal dimension could be used to describe the soil structure, soil dynamics and physical processes within the soil in order to let us have a better understanding for the performance of soil systems. By knowing the fractal dimension of soils, we can estimate several properties in soil such as texture and the moisture characteristics.

As we know, soil is fundamental to support plant growth, cycle nutrients, receive, store and transmit water, resist soil erosion and the dispersal of chemicals of anthropogenic origin. The structure of soil will have a major influence on all these ability of soil. Human activities can cause both long-term and short-term changes that may have positive or detrimental impacts on the function of the particular soil structure. If there are some changes in the soil structure, it is likely to affect the ecosystems. So, particular attention should be paid to soil structure in order to manage well the ecosystems while carry out the human activities. In this study, we have to find out the soil structure including both disturbed and undisturbed area of the Universiti Sains Malaysia (USM), Engineering Campus which located on a flat plain area in Nibong Tebal and try to find out the relationship between fractal dimension and land disturbance.

1.3 OBJECTIVES

The objectives of this study are

i. To characterize fractal dimension of soils at USM, Engineering Campus

ii. To evaluate the relationship between soil mass fractal dimension and other soil physical properties

iii. To examine whether soil mass fractal dimension reflect differences in land disturbance / management

1.4 SCOPE OF WORK

i. Soil sampling at predetermined geo-grid locations in USM, Engineering Campus

ii. Laboratory analysis of the collected soil samples to determine common soil physical properties such as bulk density, moisture content, organic content and particle size distribution

iii. Computer analysis of the soil particle size distribution to compute the mass fractal dimension of the soil particles

iv. Examine the relationship between soil mass fractal dimension and various other soil physical properties

v. Examine the relationship between soil mass fractal dimension and land disturbance / management

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Soils are complex mixture from both organic and inorganic compound. The character of soil is different from one place to another place as a result of soil formation process. Soil structure can be separated to several horizons to reflect the formation of soil. Figure 2.1 shows that the soil structure profile which formed from the physical, chemical, and biological processes.

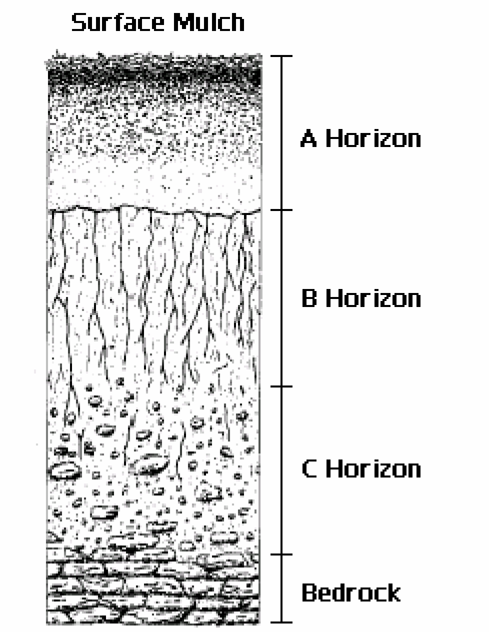

Figure 2.1. Schematic presentation of a soil profile (from Hillel, 1998)

From the research of Hillel, 1998 shows that normally the biological process is always happened at the top zone (A Horizon). The soil in this layer lies close to the ground surface and the majority root band of the vegetation lies in this horizon. Therefore, the soil color in this zone normally will become darker due to high density of organic content. The second layer from top of the soil profile (B Horizon) is generally content the leached materials such as clay, aluminum, iron hydroxides, organic matter and carbonates. For the third layer (C Horizon), it often presents the parent rock material in various stages of disruption and weathering and the bedrock normally consist after the C horizon.

As a result, variety of soil properties were form and these soil properties will vary from one place to another place. Generally, there are four soil properties important in fractal fragmentation study. The four important soil properties are organic matter, moisture content, bulk density and particle size distribution. Among these four soil properties, the particle size distribution is the most important soil properties in fractal fragmentation study because particle size distribution has a direct relationship with the fractal dimension.

Fractal dimension is a new scaling system to describe the variety natural structures. Better understanding to the material properties for natural soil will be obtained by the development of this new scaling system. Fractal dimension has been used as an index in studies of aggregate–size distributions in fragmented soils. Particle size distribution of soil often used to estimate other soil properties, such as soil moisture characteristic and hydraulic conductivities.

Soil can be separated into two categories, there are coarse-grained soil and fine-grained soil. Normally, we are using the sieve analysis to analyze the coarse-grained soil. However, there are two methods for analysis the fine-grained soil, which are hydrometer analysis and the light-scattering method analysis.

2.2 CHARACTERISTIC OF SOIL

Characteristic of soil for an area can be represented by the soil properties for that area. There are a few important common soil properties such as organic content, moisture content, bulk density and particle size distribution are influenced by soil formation process, composition of parent rocks, soil organisms, regional climate, vegetation and other soil management practices.

2.2.1 Organic Matter

Organic content is a very important mineral for the agricultural use. It can supply nutrients for the plans and help to store water in soils. Besides, from the research of Balamohan B., 2004 shows that if the soil have high percentage of organic content, then the soil need to be compacted for new constructions activities such as road pavement and building construction. Soil organic matter is a key component of terrestrial ecosystem and any variation in its abundance and composition has important effects on many processes that occur within the system (Batjes, 1996).

Organic matter will affects water holding capacity and cation exchange capacity. Also, carbon dioxide will generate during decomposition and helps promote the chemical weathering (Millan and Orellana, 2001). From the research of Gärdenäs, 1998 shows that the amount of organic matter is influenced by precipitation and temperature through (i) decomposition rates, (ii) biomass growth and litter production and (iii) transport from the humus layer to the mineral soil. Highly decomposed organic matter in the mineral soil efficiently retains water.

Torres et al. (1998) found that low density sandy loam is so highly permeable that saturated hydraulic conductivity could not be determined with the Guelph permeameter (Reynolds and Elrick 1985), because they could not maintain a constant head of water. The peat media shrank an average of 0-16 % during desorption (Heiskanen 1993). Coarse mineral soils usually retain less water than slightly decomposed Sphagnum peat, the water retention capacity of clay being of similar magnitude to that of moderately decomposed peat (Päivänen 1973). Weiss et al. (1998) noticed that their semi empirical model with only one shape parameter can be suitable for statistical investigations of peat samples.

Forest humus layers retained less water at < -10 cm than the conventionally graded peat growth media did (Heiskanen 1993). Hydraulic conductivity in the mor layer of Scots pine stand was measured using the constant-head permeater and instantaneous profile method (Laurén and Heiskanen 1997). The unsaturated hydraulic conductivity decreased from 3.1×10^{-3} to 1.1×10^{-8} md^{-1}. Laurén and Mannerkoski (2001) found that the hydraulic conductivity and the water retention of the mor layers varied considerably within Finnish pine and spruce stands.

2.2.1.1 Relationship Between Organic Matter And Mass Fractal Dimension

Garey (1954) observed that the smaller aggregates (0.15-0.42 mm) have higher cation exchange capacities, and have larger amounts of clay and organic matter than of the whole soil. The stability of microaggregates is insensitive to changes in either the soil organic matter content or soil management practices (Tisdall and Oades, 1982). Microaggregates are very stable because they are bound by persistent aromatic humic material associated with amorphous Fe and Al compounds. The stability of macroaggregates, on the other hand, varies with the changes in organic matter content or in management practices.

Monreal et al. (1997) found that the macroaggregate stability is correlated to many types of organic matter structures such as lignin dimers, alkylaromatics, lipids, sterols, organic carbon and nitrogen. The microaggregate stability, however, failed to correlate to any of the organic matter structures. They concluded that soil organic matter and its entities may be less important than the inorganic components in stabilizing microaggregates.

Although organic matter increases with decreasing aggregate size (Gupta and Germida, 1988), the organic matter in the smaller aggregate size fractions are older, less liable and more highly processed than the organic matter in larger aggregates (Gupta and Germida, 1988). When decreasing the aggregate size, the mass fractal dimension will be increase. So, we can say that when organic matter increase, mass fractal dimension of the soil also increase.

2.2.2 Moisture Content

Moisture content, w is the ratio, often expressed as a percentage, of the weight of water to the weight of solids. It formula is :

$$Moisture\,content, w = \frac{Weight\ of\ water, Ww}{Weight\ of\ solid, Ws} \tag{1}$$

Moisture content is one of the important soil properties for the fractal fragmentation study. Besides the fractal fragmentation study, moisture content also important in calculate the liquid limit, plastic limit and shrinkage limit (Budhu, 1999). Besides, Zhang and Anthes (1982) had also studied the effects of soil moisture variations on planetary boundary layer depth and circulation. It shows that the soil moisture content also affects the vertical ground temperatures, boundary layer depths, pressures and velocities.

2.2.2.1 Relationship Between Moisture Content And Mass Fractal Dimension

The mass-size dependence for such aggregates differs from that in dry aggregates because soil shrinks as water content decreases. It appeared that the wetter aggregates are the less prone to loosening as the water increases. Aggregates in field soil are not air-dry. The relationships between mass and size differ between dry aggregates and wet aggregates because aggregates shrink as water content decreases (Pachepsky and Guber, 2004).

If the percentage of clay content is high, then the moisture content also will become higher. Also, the mass fractal dimension will be increase while increasing of clay content. So, we can say that when the water content increase, the mass fractal dimension will be increase.

2.2.3 Bulk Density

Bulk density is the weight of a soil per unit volume. It also use the term unit weight to denote the bulk density (Budhu, 1999). The density-size relation showed a scale-variant behaviour (Millan and Orellana, 2001). Higher bulk density is good for any construction to carry out. Millan and Orellana (2001) suggested that the bulk density of an aggregate of unit length could be used as a measure of soil compaction.

However, low density soil is required to have a higher infiltration rate. So the bulk density of the soil should maintain and take good care to minimize the problem occur for any construction propose to carry out.

2.2.3.1 Relationship Between Bulk Density And Mass Fractal Dimension

Relationships between density of dry soil aggregates and aggregate size present a different way to use aggregate-related information in soil structure characterization. Relationships between density of dry soil aggregate and aggregate size have been simulated assuming soils to be mass fractals (Pachepsky and Guber, 2004). Gimenez et al. (1994) working with three soils in the data set of Logsdon et al. (1990) have shown that the aggregate bulk density–size relationship was fractal with D_m between 2.85 and 2.89. Rieu and Sposito (1991b) have also found that mass and bulk density of aggregates followed a fractal distribution with fractal dimensions between 2.88 and 2.95. According to fractal scaling theory, the values of mass fractal dimensions less than 3 signify a scale-dependence in aggregate bulk density.

The reference bulk density decreased as the water content increased (Pachepsky and Guber, 2004). Also, the density-size relation showed a scale-variant behaviour (Millan and Orellana, 2001). So we can say that the fractal theory were simple linear functions of the water content. Moreover, fractal dimension will be increase when the soil has higher clay content. In addition, if the soil has higher clay content, then the water content will also become higher. So, when the bulk density of a given soil was increase, the mass fractal dimension of that given soil will be decrease.

2.2.4 Particle Size Distribution

Particle-size distribution in soil is one of the more fundamental soil physical properties. It is widely used for the estimation of soil hydraulic properties such as the water-retention curve and saturated as well as unsaturated conductivities (Arya and Paris, 1981). Particle size distributions are commonly used to characterize soil structure (Pachepsky and Guber, 2004).

The technique that employed for the particle size distribution analysis is similar to that commonly used in soil mechanics, where the size groups each with a size in diameter larger than a certain value are established through the sieve analysis, and the remaining groups by the hydrometer analysis (Tang et al., 1979).

2.2.4.1 Relationship Between Particle Size Distribution And Mass Fractal Dimension

Soil aggregate analysis presents an important characterization of soil structural organization. Experiments with dry soil aggregates have shown that the mass of aggregates changes with their size so that the aggregates become looser as their size increases. Such dependence has been successfully explained by the fractal scaling theory, and predictions of this theory are in good agreement with experimental data. The theory furnishes two parameters to characterize mass-size relationships. One of them is the exponent that shows how pronounced is the loosening with the size increase. Another parameter shows the reference bulk density for aggregates of the unit size (Bittelli et al., 1999).

Generally, a conventional particle-size analysis involves the measurement of the mass fractions of clay, silt, and sand. The mass-based fragmentation approach was used to analyze experimentally determined particle size distribution data (Bittelli et al., 1999). From the study of Gimenez et al. (1994) found that the mass fractal dimension increased as the fraction of clay-sized particles increased about 10%. Bittelli et al. (1999) and Tyler and Wheatcraft (1992) have also reported values of fragmentation fractal dimensions increasing with increasing of clay contents.

The fractal dimension increases with clay content, and decreases with sand content. These results suggest that the power-law relation can be used to characterize particle size distribution in soils, and may be an alternative to the conventionally used approaches, such as the lognormal distribution (Bittelli et al., 1999).

2.3 FRACTAL

One of the latest developments in the study of particle size distribution in soils has focused on the use of fractal mathematics to characterize particle sizes in soil (Tyler and Wheatcraft, 1992; Wu et al., 1993). However, questions remain about the validity and applicability of fractal concepts to particle size distribution. There has been some discussion about the proper use and definition of the term “fractal” in the literature (Young et al., 1997; Baveye and Boast, 1998). Different concepts of fractals are used, and these concepts lead to different interpretations of fractal dimensions obtained. Therefore it is essential to clearly specify the type of fractal model used. Perfect and Kay (1991) also applied fractal theory to the characterization of soil structure. They used the algorithm of Turcotte (1989) that assumes scale-invariant fragmentation.

Fractals are the concern of a new geometry, whose primary object is to describe the great variety of natural structures that are irregular, rough or fragmented, having irregularities of various sizes that bear a special ‘scaling’ relationship to one another (Mandelbrot, 1982). Developments in fractal geometry have led to a better understanding of material properties and apparently chaotic processes in nature.

It has long been recognized that the behavior of water in soils depends on pore space geometry. Quantification of this geometry by means of fractal concepts offers an opportunity to relate water properties to soil structural properties and fractal geometry has recently been used to describe both soil structure and soil hydraulic properties (Giménez et al. 1997). Soil structural properties seem to follow power law functions. The exponent of these functions can be interpreted in terms of fractal dimension, which may be related to soil structural characteristics. Pachepsky et al. (1995) have shown deviation from the power law and explains this being due to the multifractal structure of soil porosity, which results in dependence of the fractal dimension on the radii of soil.

The water retention curve model of Pachepsky et al. (1995) assumes fractal selfsimilarity of pore volumes by adding a correcting factor accounting for the dependence on the radii of soil. The chosen factor, f(r), is a log-normal probability distribution function of the pore radii of soil. The fractal model of Rieu and Sposito (1991a) contains seven predictive equations and they tested it experimentally with data on aggregate characteristics and soil water properties for structured soils. For the single set of aggregate/soil water properties data available, good agreement was found with the fractal model for water potential and scaling relationship and the moisture characteristic and hydraulic conductivity-water content relationships (Rieu and Sposito

1991b). Rieu and Sposito (1991a, b) have shown that power functions for the aggregate size distribution and the water retention curve directly stems from a fractal model of aggregate and pore space properties for structural soils.

Arya and Paris (1981) model was shown that the empirical constant is equivalent to the fractal dimension of a tortuous fractal pore (Tyler and Wheatcraft 1989). Ten soils for which water retention and particle size data were available were analysed to obtain both the fractal dimension and subsequently the water retention data using the Arya and Paris (1981) model. The soil textures ranged from sand to silty clay loam. The results indicated that water retention characteristics data could be estimated with reasonable accuracy for soils in which the particle size data shows power law scaling with a fractal dimension of > 3.0. Such soils are those with a wide range of particle sizes.

Perfect and Kay (1991) concluded that although fractal objects provide idealized and simplified models of real porous media, they do give valuable insight into the geometrical coherence that must underlie any attempt to relate fractal dimensions corresponding to different physical definitions with those describing water retention curves.

2.4 FRACTAL DIMENSION

Fractal dimension, D, has been used as an index in studies of aggregate–size distributions in fragmented soils (Rasiah et al., 1992). In practice, data on number–size distributions are obtained from mass–size distributions (Rasiah and Biederbeck, 1995). Pachepsky et al. (1995) found that simulated soil degradation caused an increase in fractal dimensions of soil in one or more intervals of fractal behavior. Fractal parameters are also affected by long-term management practices (Pachepsky et al., 1996).

Particle size distributions are often rendered as cumulative functions, either as number of particles larger than a certain diameter, or as mass smaller than a certain diameter. These cumulative distribution functions have been analyzed with power-law relations and the exponents interpreted as fractal dimensions. Tyler and Wheatcraft (1989, 1992) analyzed particle-size data ranging from 0.5 mm to 5000 mm radii, and observed that the fractal power law was not valid across the entire extent of particle sizes. It is expected that there are lower and upper limits to the validity of fractal relations (Turcotte, 1986).

Wu et al. (1993) measured particle size distribution down to 0.02 mm radius by using light scattering techniques, and found a power-law relation between number of particles and particle radius valid across a range of particle radii with a lower cutoff between 0.05 mm and 0.1 mm and an upper cutoff between 10 mm and 5000 mm. Kozak et al. (1996) analyzed particle size distribution of 2600 soil samples and found that for 50% of the samples power-law scaling of particle numbers vs. size was not applicable across the whole range of particle sizes between 2 mm and 1000 mm.

Bittelli et al. (1999) indicate that power-law scaling might be applicable for a narrower range of particle sizes, although this was not analyzed in their study. Assuming that the exponent of a power-law relation is a fractal dimension, Wu et al. (1993) found a dimension of $D = 2.8 \pm 0.1$ for four soils studied and suggested that this might be a universal value of an underlying structure.

Most applications of fractal concepts to particle size distributions are based on the fragmentation model of Matsushita (1985) and Turcotte (1986). The power-law exponent of the number-based approach can be interpreted as fractal dimension (Matsushita, 1985; Turcotte, 1986). The sorting of particles by size in the fragmentation model results in fractal dimensions ranging theoretically between the limits of 0 and 3 (Turcotte, 1986).

A power-law relation between the number and size of objects has been proposed (Mandelbrot, 1982; Matsushita, 1985; Turcotte, 1986) :

$$N(r > R) = CR^{-D} \tag{2}$$

where $N(r > R)$ is the number of objects per unit volume having a radius r larger than R, C is a constant of proportionality, and D is the fractal dimension. Borkovec et al. (1993) experimentally determined fractal dimensions of fragmentation and surface areas of soil particles and found the two dimensions to be 2.8 ± 0.1 and 2.4 ± 0.1, respectively.

Euclidean initiators have been used to model the fragmentation of solid materials. Fractal initiators may be more appropriate for predicting the fragmentation of porous media. General expressions for the fragmentation of classical and fractal cubic initiators is assuming scale-invariant probabilities of failure, P (Perfect et al., 1991). For classical cubes $D = 3 + \log(P) / \log(b)$, where D is the fragmentation fractal dimension and b is the scaling factor. For fractal cubes $D = d + \log(P) / \log(b)$, where d is the mass fractal dimension of the fractal cubic initiator (Perfect et al., 1991).

Bittelli et al. (1999) denote the three fractal dimensions determined in thier study as D_{clay}, D_{silt}, and D_{sand}. The fitted values of the fractal dimensions obey in all cases the relation: D_{clay}, D_{silt}, D_{sand}. In the clay domain, the fractal dimension ranged from 0.118 to 1.21, in the silt domain from 1.728 and 2.792, and in the sand domain from 2.839 to 2.998. These data are consistent with the limits of the fragmentation approach given as $0 < D < 3$ (Turcotte, 1986). The fragmentation of a cube has a certain probability p, which is assumed to be constant for all orders of fragmentation. A cube can maximally disintegrate into eight smaller cubes ($p = 1$) and minimally into one smaller cube ($p = 1/8$). As shown by Turcotte (1986), the fragmentation probability p is related to the fractal dimension D by

$$D = \frac{Log(8p)}{Log\ 2} \tag{3}$$

where the range of possible fractal dimensions is $0 < D < 3$.

2.5 MASS FRACTAL DIMENSION

Soil aggregates have a fractal mass. That is, they are porous and, as they are studied in greater detail, more pores may be observed (Anderson and Mcbratney, 1995). Fractal fragmentation models can be classified as either energy or probability-based (Takayasu, 1990) including mass-conserving (Turcotte, 1989, 1992) and reductive (Rieu and Sposito, 1991a).

Perfect et al. (1993) developed a fractal fragmentation model in which the fractal dimension is a smooth function of scale. In the context of the present work we applied a mass-conserving fractal model for the analysis of the mass–size relationship and the Menger sponge model for the bulk density–size relationship (Rieu and Sposito, 1991a; Perfect and Kay, 1995).

The mass fractal dimension, D_m, has been considered the most relevant. D_m is estimated from the following power–law relationship (Bartoli et al., 1991; Young and Crawford, 1991) :

$$M_i = A_m l_i^{Dm} \qquad (4)$$

where M_i is the mean individual aggregate mass for the ith fraction, A_m is a constant expressing the mass at the 1-mm length scale, l is an estimator of the aggregate size left on the ith sieve.

Mass fractals also have scale-dependent bulk density. Larger objects, or soil aggregates, have a smaller bulk density. The fact that soil aggregates are mass fractals places restrictions on the estimation of the fragmentation fractal dimension (D) of soil. The mass fractal dimension of soil (D_m) may be calculated from bulk density-aggregate size data. The D_m is shown to influence porosity and the saturated water content. Fractal theory, in particular D_m, has implications for the calculation of the pore-size distribution and the moisture characteristic (Anderson and Mcbratney, 1995). By equating Campbell's (1985) Version of the Brooks-Corey water retention function, Proportional ø(–1 / b) and an equivalent form to the Brooks-Corey relation given by Crawford (1995), Proportional ø(D_m – d) it is suggested that $D_m = d - 1/b$, where d is the embedding dimension.

In the model of Matsushita (1985) and Turcotte (1986), the fragmentation of an initially intact particle into smaller particles leads to a power-law relation between number and mass of particles as a function of particle size. These two types of fragmentation relations are known as number-based and mass-based approaches (Turcotte, 1992). The mass-based approach is compatible with data obtained from experimentation, where usually mass fractions rather than number fractions are measured. The mass-based form is expressed as (Turcotte, 1986; Tyler and Wheatcraft, 1992)

$$\frac{M(r < R)}{M_T} = [\frac{R}{R_{L,upper}}]^v \tag{5}$$

where M(r < R) is the mass of soil particles with a radius smaller than R, M_T is the total mass of particles with radius less than $R_{L,upper}$, $R_{L,upper}$ is the upper size limit for fractal behavior, and *v* is a constant exponent.

2.6 USEFULNESS OF MASS FRACTAL DIMENSION

In the area of soil science and engineering, mass fractal dimension are used recently to determine the shear strength of unsaturated soils (Xu and Sun, 2002) and soil cohesion (Bonala and Reddi,1999), to evaluate spatial characteristics of soil surface strength (Folorunso et al.,1994), to study soil microstructure (Xu and Liu, 1999; Moore and Donaldson, 1995), to simulate water through saturated soils (Thevanayagam et al., 1998), and to model soil density, porosity and soil–water properties (Rieu and Sposito, 1991; Niemeyer and Machulla, 1999).

The application of mass fractal dimension to describe soil structure, soil dynamics, and physical processes within soil is becoming an increasingly useful tool that allows for a better understanding of the performance of soil systems. The fractal dimension of particle-size distributions is often used to estimate several properties in soils, such as texture and moisture characteristics (Iverson et al., 1989).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The USM, Engineering Campus was chosen as the area of this study. The coordinates of this area was established by a Global Positioning System (GPS) survey and the boundary data was obtained by using the surfer software. After the map of USM, Engineering Campus generated, this area was separated into a number of grid lines. The location of soil sample collection is at the intersection of the grid lines. Figure 3.1 shows the map of USM, Engineering Campus and the location of the soil sample collection.

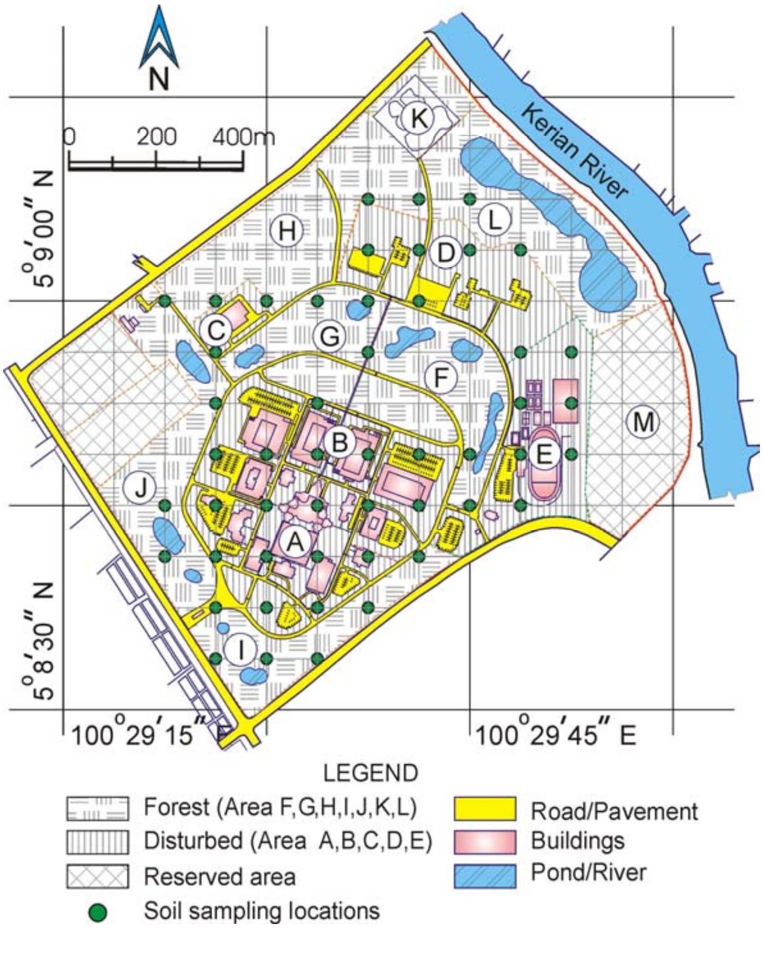

Figure 3.1. Map of USM, Engineering Campus and soil sample location

The collected soil samples were sent to do the laboratory test. The laboratory test are including the particle size distribution for both sieve analysis and hydrometer analysis, bulk density, moisture content and organic content. After the results of the soil properties were obtained from the laboratory tests, these results were used in finding the fractal dimension.

The mass fractal dimension of a soil sample is found from the results of the soil particle size distribution of soil sample. All mass fractal dimension for soil samples were used for investigate two relationship, which are:

i. Relationship between mass fractal dimension and variety soil properties
ii. Relationship between mass fractal dimension and land disturbance/management

3.2 SITE DESCRIPTION

3.2.1 Location of USM, Engineering Campus

Universiti Sains Malaysia (USM), Engineering Campus is located on lots 4312, 4313, 4314, 3761, 3763, 3764, 1766, 1769 and 1767 in Mukim 9 of Daerah Seberang Prai Selatan, Pulau Pinang. It latitudes is within $100^0$29.5’ South and $100^0$30.3’ North and it longitudes is within $05^0$09.4’ East and $05^0$08.5’ West. The total area of this campus is about 137 ha or about 320 acres. This area is known as Ampang Jajar, Nibong Tebal and is located about 2 km south-east from town of Nibong Tebal (Penang), about 1.5 km north-east from the town of Parit Buntar (Perak) and about 1.5 km north-west from the town of Bandar Baharu (Kedah). The campus is located within the triangle of development area where include three states of Pulau Pinang, Perak and Kedah.

The majority of soil for this campus is clay because this area is a formal oil palm plantation. The foreign soils have to transfer in to this area in order to prepare the suitable surface for the construction of the campus. Due to the quality of soil is not good, the foundation of the buildings are using the piling system.

3.2.2 Classification of land disturbance

The map of the USM, Engineering Campus is separated into 13 zones and is shows in Figure 3.2. The classification of the land disturbance is base on the zone. There are two categories of the land disturbance which are disturbed area and undisturbed area.

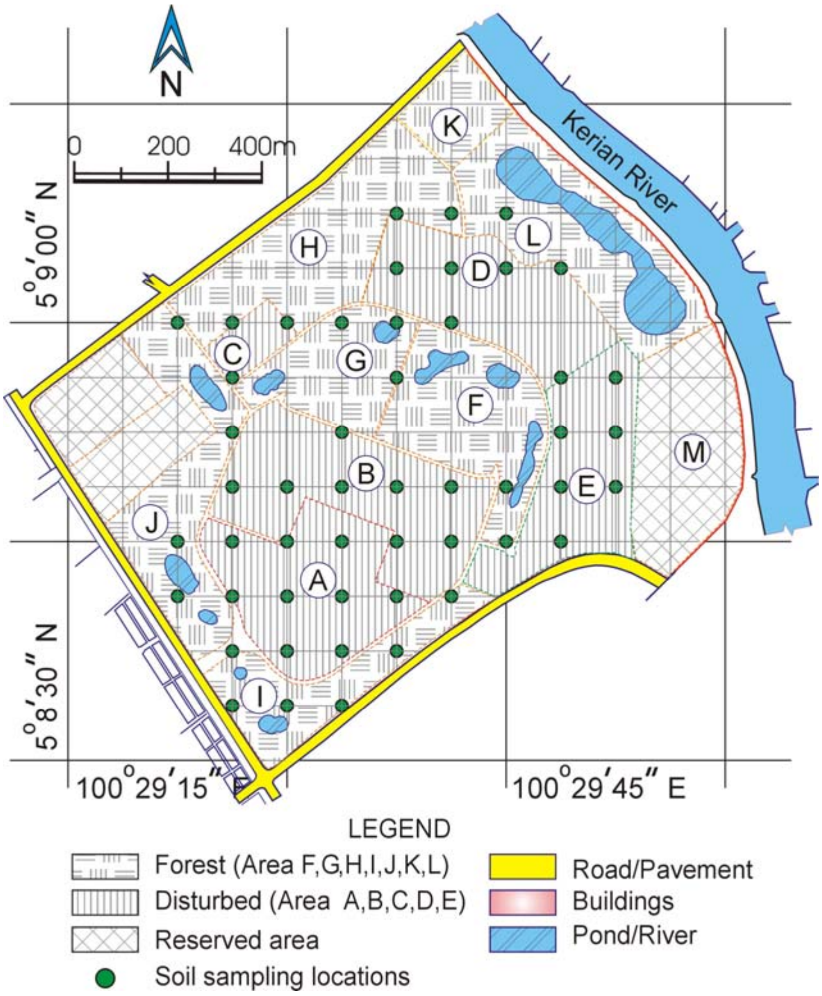

Figure 3.2. Zone of USM, Engineering Campus

Disturbed area generally is referred to the area that the original soil structure was disturbed due to the human activities such as building construction, road pavement and land compaction. Zone A, B, C, D and E in Figure 3.2 are classified as disturbed area due to the human activities already done on it.

However, undisturbed area normally is referred to the area that the soil structure of this area is still form by the original natural soil. This kind of area does not disturbed by any human activities and the soil is form by the natural weathering process. Soil from the forest normally is considered as the undisturbed area because the soil structure of that area doesn't disturbed by any human activities. Zone F, G, H, I, J, K, L and M in Figure 3.2 are considered as undisturbed area because these zone are forest and reserved area.

3.3 SOIL SAMPLING

The soil samples were collected at the predetermined grid location the shows in Figure 3.1. The soil samples collection were done by Balamohan B. (2004) and the data were used in this research.

3.4 LABORATORY TESTS

There is some laboratory tests should carry out by followed the standard procedures stated in BS1377: Part 2&3: (1990) for the soil samples that had collected from the soil sampling activities. Normally, we should carry out the particle size distribution test, bulk density determination test, calibration of moisture content test and calibration of organic content test. These laboratory tests were done by Balamohan B. (2004) and the data were used in this research.