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Kertas Asli/*Original Article*s

Physical and Chemical Characteristics of Oil Palm Plantation Soil: A New Lead in Forensic Investigation

(Ciri-ciri Fizikal dan Kimia Tanah Ladang Kelapa Sawit: Petunjuk Baru dalam Penyiasatan Forensik)

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ABSTRACT

Soil sample is one of the important evidence that can be found in crime scene. Unknown soil sample can be analysed and compared with reference sample in order to determine the origin as its physical and chemical components possess unique characteristics. The purpose of this study is to determine the physical and chemical characteristics of soil from oil palm plantations in Perak, Malaysia to assist forensic investigation. Total of 97 topsoil samples were collected from three different oil palm plantations in Perak. Particle size distribution was obtained using dry sieving technique and colour of soil sample was examined under three conditions that are dry, moist and ashed. Soil pH was measured using pH meter and percentage of composition of soil organic matter (SOM) was determined by weighing the sample before and after ignition. Result showed that the composition of particle size <0.18mm was within the range of 5.57-21.11% whereas for particle size between 0.18mm - 0.6mm was within 31.62 - 52.96% and 25.78-66.86% for particle size >0.6mm. The color mode of soil after oven dried, moistened and ashed was greyish brown (10YR 5/2), very dark greyish brown (10YR 3/2) and light yellowish brown (10YR 6/4) respectively. Soil pH was in the range of 5.79 – 6.70. The percentage of SOM was between 3.29 - 20.48%. The physical and chemical characteristics of soil analysed in this study from three different locations of oil palm plantations varied and it is possible to discriminate these locations based on the analysis highlighted in this study.

Keywords: Oil palm plantation; geoforensics; soil sample; soil analysis; soil characteristics

ABSTRAK

Sampel tanah merupakan salah satu bahan bukti penting yang boleh dijumpai di tempat kejadian. Sampel tanah yang tidak diketahui boleh dianalisis dan dibandingkan dengan sampel rujukan untuk menentukan asal usul memandangkan komponen fizikal dan kimianya mempunyai ciri yang unik. Tujuan kajian ini dijalankan adalah untuk menentukan ciri fizikal dan kimia tanah dari ladang kelapa sawit di Perak, Malaysia dalam membantu penyiasatan forensik. Sebanyak 97 sampel tanah permukaan diambil dari tiga ladang kelapa sawit yang berbeza di Perak. Taburan saiz partikel diperolehi menggunakan teknik ayakan kering dan warna sampel tanah dikaji dalam tiga keadaan iaitu kering, lembap dan dibakar. pH tanah diukur menggunakan meter pH dan peratusan komposisi bahan organik tanah (SOM) ditentukan dengan menimbang sampel tanah sebelum dan selepas pembakaran. Keputusan menunjukkan komposisi saiz partikel <0.18mm adalah dalam julat 5.57-21.11% manakala, saiz partikel di antara 0.18mm - 0.6mm adalah dalam lingkungan 31.62 - 52.96% dan 25.78-66.86% untuk saiz partikel >0.6mm. Mod warna tanah selepas pengeringan menggunakan ketuhar, lembap dan dibakar masing-masing adalah coklat kelabu (10YR 5/2), coklat kelabu gelap (10YR 3/2) dan coklat kekuningan (10YR 6/4). pH tanah adalah di antara 5.79 – 6.70. Peratusan SOM pula adalah di antara 3.29 - 20.48%. Kesimpulannya, ciri-ciri fizikal dan kimia tanah yang dianalisa dalam kajian ini daripada tiga lokasi ladang kelapa sawit yang berbeza adalah bervariasi dan boleh untuk membezalayan lokasi tersebut berdasarkan analisis yang ditekankan di dalam kajian ini.

Kata kunci: Ladang kelapa sawit; geoforensik; sampel tanah; analisis tanah; ciri tanah

INTRODUCTION

Forensic geoscience or geoforensics is one of the essential sub-disciplines in forensic science (Mazhari 2010). Geoforensics uses geological approach for legal purposes (Morgan & Bull 2007). Since it covers broad range of details and closely related to other disciplines, it overlaps with few other fundamental sciences. One of it is forensic soil science which is a study of soil to solve judicial problems or hypotheses (Fitzpatrick 2013).

According to soil scientists, the composition of soil is mainly mineral particles which varies in size such as sand, silt and clay. Other than that, it composed organic matters which consist of living microbiota and humus, roots of plants, decomposed plants and remains of animal (Dawson & Hillier 2010). Complicated biological, chemical, physical, mineralogical and hydrological properties also possessed by soil which is subject to change over the time (Fitzpatrick 2013).

Since soil is a complex substance, various analysis can be done and information that can be obtained is diverse. Both the complexity and diversity factors of soil is an advantage and limitation simultaneously in forensic soil science (Dawson & Hillier 2010). This is because complexity which results in distinct characteristics can be a 'fingerprint' of a soil sample. However, creating database for reference became nearly impossible due to the diversity in this complexity.

Soil serves as a good and reliable contact trace or evidence because it's individualistic property. Soil is highly individualistic due to its variety of biological, chemical, mineralogical and physical properties (Marumo 2003). In forensic investigation, soil may adhere to tyre, carpet, clothing, shoes or instruments such as shovel, hence suspect will take little or no attempt to destroy the evidence (Fitzpatrick & Raven 2012). Furthermore, presence of fine particles such as clay and slit size fractions make soil to have great ability to adhere and stick on other surfaces hence it possesses high retention and transfer rate.

In forensics, information regarding soil's properties are crucial to determine a specific location (if the crime scene is unknown) such as in Double Murder Case whereby the location of the victims was determined by analysing soil adhered to blood-stained shovel which was found in one of the victim's missing car (Fitzpatrick & Raven 2012). In Malaysia, there are a number of murder cases that took place in oil palm plantations namely the murders of Datuk Sosilawati Lawiya (Anon 2010) and Dirang (Anon 2013).

According to Mutert (1999) alluvial type of soils seemed to be the most suitable soil for oil palm plantation. More specifically, this type of soil in Peninsular Malaysia may vary from clayey and silty to sandy (Shamshuddin 1986). Examination of soils can be carried out in many aspects. This includes physical analysis, elemental analysis, mineralogy, chemical method, palynology and identification of botanical fragments. However, this research only focuses on physical and chemical characteristics of soil, specifically oil palm plantation soils.

METHODOLOGY

SAMPLES

A total of 97 topsoil (0-10cm depth) samples were collected from Ladang Rakyat A (Air Kuning, Perak) (35 samples), Ladang Rakyat B (Air Kuning, Perak) (30 samples) and Ladang Dovenby (Sungai Siput, Perak) (32 samples). 100g of soil were collected from each location. Each of soil sample was homogenized by mixing manually.

PHYSICAL PROPERTIES

PARTICLE SIZE DISTRIBUTION

Three different soil particle sizes was determined (>0.6 mm, 0.18 mm-0.6 mm and <0.18 mm). 5 g of soil sample was added to a 0.6 mm sieve and sieved completely. The particles that passed through the 0.6 mm sieve were weighed and subtracted from initial weight and the result was recorded as weight of soil particles >0.6 mm. Then, the particles that passed through 0.6 mm sieve were sieved using a 0.18 mm sieve. The particles that passed through this 0.18 mm sieve were weighed and recorded as weight of soil particles <0.18 mm. Weight of soil particles that passed through 0.6 mm sieve was subtracted with weight of soil particles <0.18 mm and the result was recorded as weight of soil particles between 0.18 mm-0.6 mm. Percentage of particle size distribution was calculated. Mean value of percentage of soil particle size distribution was calculated for each size examined and compared with all three oil palm plantations. The data was further analysed using Kruskal-Wallis test.

COLOUR

Soil samples were divided into 3 conditions: moist, dry and Ashed soil. 3g of soil was oven-dried under 100^{0}C (dry condition), 3g of soil and distilled water were added to a beaker with ratio of 1 to 1 (moist condition) and 3g of soil was placed in electric furnace under 650^{0}C for 30 minutes (ashed soil). The colour of the soil under three different conditions was then compared with Munsell Colour Book (Appendix B) and recorded.

CHEMICAL PROPERTIES

pH

6 g of soil sample was placed into a beaker and distilled water was added with 1 to 1 ratio. The mixture was then stirred and left for 10 minutes. The pH value of the solution was then measured using electronic pH meter. As a control the pH value of the distilled water was measured as well. Mean value of pH for each oil palm plantation was calculated

SOIL ORGANIC MATTER (SOM)

5 g of sample was placed in oven under 100^{0}C. The dried sample was then sieved using 0.6mm sieve and weighed. The samples then placed in the furnace under 650^{0}C for 30 minutes. After cool down the samples were weighed again and substracted from its dry weight. Then the percentage of SOM was calculated. Mean value of SOM for each oil palm plantation was calculated and compared. The data was further analysed using analysis of variance (ANOVA) and Tamhane's Post Hoc test.

RESULTS

PARTICLE SIZE DISTRIBUTION

Majority of soil samples at Ladang Rakyat A, Ladang Rakyat B and Ladang Dovenby have particles size >0.6mm and within the range of 0.18mm-0.6mm as shown in Figure 1. Kruskal-Wallis test (Table 1) showed that there was no significant difference between the soil particle size greater than 0.6mm and for particle size between 0.18mm – 0.6mm in all oil palm plantations ($p>0.05$). However, there was a significant difference for particle size less than 0.18mm ($p<0.05$).

COLOUR

Oven-dried soil expressed 14 different colours for all three oil palm plantations (Figure 2). The mode of colour for oven-dried soil was 10YR 5/2 (greyish brown). Upon ashing, soil samples expressed huge range of colours (21 different colours) as compared to the oven-dried and moistened condition where the mode colour was 10YR 3/1 (very dark grey) (Figure 4). Meanwhile, soil samples expressed 15 different colours when moistened and the

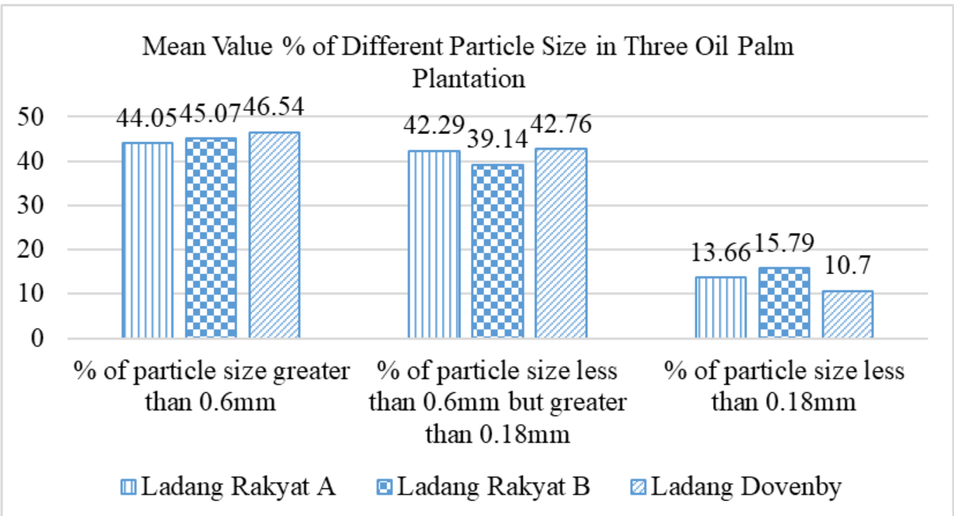

FIGURE 1: Mean value percentage of different particle size distribution at Ladang Rakyat A, Ladang Rakyat B and Ladang Dovenby

TABLE 1. Kruskal-Wallis test for particle size distribution

	% of particle size > 0.6mm		% of particle size 0.18mm - 0.6mm		% of particle size < 0.18mm	
Location	Mean rank	P value	Mean rank	P value	Mean rank	P value
Ladang Rakyat A	45.64		51.39		49.58	
Ladang Rakyat B	47.50	>0.05	38.50	>0.05	61.33	<0.05
Ladang Dovenby	50.91		53.41		33.88	

mode of colour was 10YR 3/2 (very dark greyish brown) (Figure 3). When outcome of each soil samples (Appendix A) were examined, the soil sample with similar dry colour does not express exact same colour upon moistening and ashing (Table 2).

pH

Average value of pH for Ladang Rakyat A, Ladang Rakyat B and Ladang Dovenby were 5.79, 6.29 and 6.67 respectively (Figure 5). ANOVA test shows that pH value was significantly different between 3 oil palm plantations ($p<0.05$) (Table 3).

SOIL ORGANIC MATTER (SOM)

Average percentage value of SOM for Ladang Rakyat A, Ladang Rakyat B and Ladang Dovenby was 12.49%, 11.42% and 4.38% respectively (Figure 6). ANOVA test shows that percentage of SOM differs significantly between groups. Tamhane's Post Hoc test (Table 4) shows that there was significant difference between following pairs: Ladang Dovenby – Ladang Rakyat A and Ladang Dovenby – Ladang Rakyat B.

DISCUSSION

PARTICLE SIZE DISTRIBUTION

According to the United State Department of Agriculture (USDA 1987), soil can be classified into texture based on diameter range of soil particle size (Table 5). In this study, there is no significant difference in particle size more than 0.6mm and between 0.18 mm - 0.6 mm in all three oil palm plantations (Table 1). Hence, soil samples in all three oil palm plantation has a mixture of course, medium and fine sand. For particle size less than 0.18 mm, there is significant difference among all three oil palm plantations. This shows that the mixture of very fine sand, silt and clay varies in proportion according to different places.

Dry sieving is a suitable method to determine particle size which ranges from 40 µm to 125 mm whereas the measurement range extends up to 20 µm when wet sieving technique is used. In this case, dry sieving method is used as the size of interest is more than 40 µm. Although hand sieving may consume much time but it is essential for reliable dry sieving data (Allen 2003). Although there are more advance methods available to determine particle size distribution such as Bouyoucos hydrometer method and automated particle size analyser, quantitative sieving is still favourable as it is inexpensive yet desires high confidence in its outcome. The data of sieve analysis also proven highly reproducible even with usage of various sieve sets (Allen 2003).

COLOUR

As reported by Sugar Research Australia (2014), soil colour depends on the quantity and condition of soil organic matter as well as iron oxide and soil aeration. Blackish brown soils are rich in organic matters. However, presence of clay minerals may cause the soil to appear dark as well. On the other hand, soils with reddish brown colour are oxygen rich. Ample oxygen content causes iron within the soil to oxidised readily and exhibit rusty-like colour. Yellowish brown soil has bad drainage which causes the iron in soil to be in hydrated condition, meanwhile light greyish soils appears as if washed-out due to iron and manganese that leached out as a result of greater rainfall. It may also due to vertical or lateral drainage.

In this study, although soil samples exhibit similar colour when oven dried, all of them do not turn into similar colour upon moistening (Table 2). For example, there were 7 samples that grey (10YR 5/1) in colour when oven dried. With presence of moisture, 4 out of 7 samples exhibited very dark greyish brown colour (10YR 3/2), while the other three samples turned into black (10YR 2/1), dark greyish brown (10YR 4/2) and brown (10YR 4/3) respectively. Similar findings also stated by Dudley (1975), he suggested that moistened soil is a great mean to distinguish soils with similar dry colour.

When soil sample was exposed at very high temperature (ashed), the soil material undergone numerous process such as minerals dehydration, clay mineral dihydroxylation, organic material removal and minerals destruction (Crampton 1972). According to Dudley (1975), the more the temperature elevated, the more changes will occurs to the soil sample in all aspects stated by Crampton (1972). This correlates with this study in which similar soil showed different colour when oven dried at 100ºC and ashed at 650ºC. For instance, soil sample No.3 from Ladang Rakyat B exhibited 10YR 4/3 colour when in dry form while 10YR 3/1 colour after ashed (Table 2). It was found that ashing the soil discriminate the sample better than moistening it. This is because when all 5 samples with 10YR 4/3 colour was ashed, it turned to 4 different colours which were 10YR 3/1, 10YR 6/2, 10YR 4/4 and 10YR 5/8 whereas only express two types of colours; 10YR 3/3 and 10YR 3/2 after moistened (Table 2). However, Sugita and Marumo (1996) reported that colour determination on ashed soil is useless and unnecessary compared to colour examination of soil after organic matter composition and iron removal in combination with moistened and air-dried soil. Based on

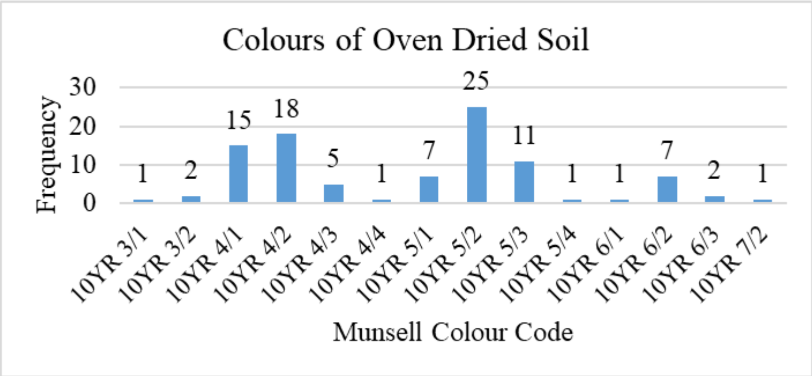

FIGURE 2: Overall frequency of soil colour after oven-dried for Ladang Rakyat A, Ladang Rakyat B and Ladang Dovenby

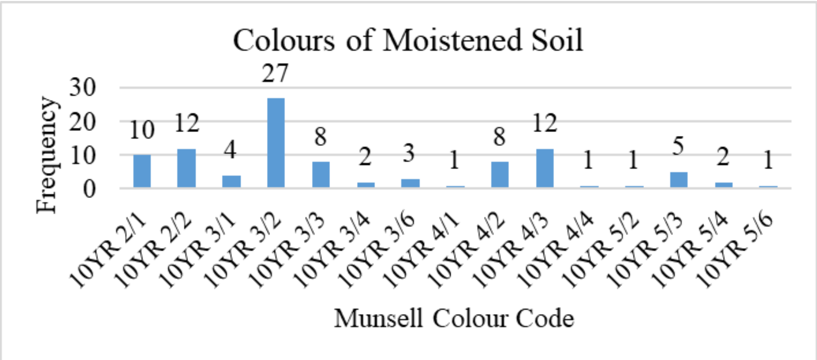

FIGURE 3: Overall frequency of soil colour after moistened for Ladang Rakyat A, Ladang Rakyat B and Ladang Dovenby

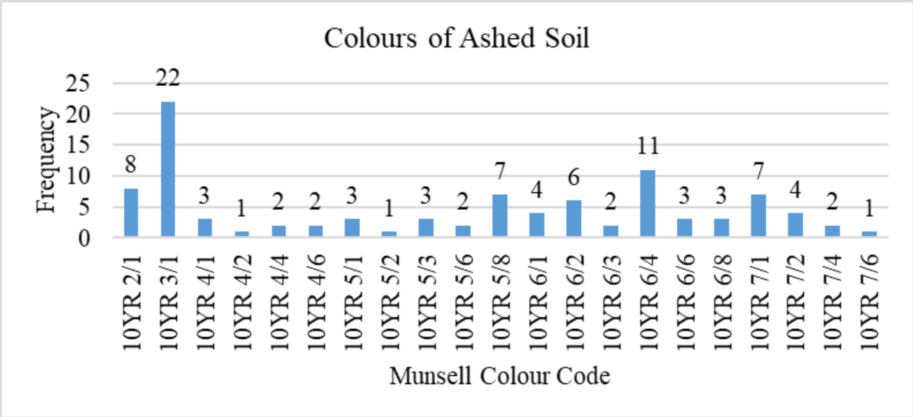

FIGURE 4: Overall frequency of soil colour after ashed for Ladang Rakyat A, Ladang Rakyat B and Ladang Dovenby

TABLE 2. Colour variation of dried, moistened and ashed soil.

Sample Origin	Dry Colour	Moistened Colour	Ashed Colour
Ladang Rakyat A (No.11)	10YR 5/1	10YR 4/2	10YR 7/1
Ladang Rakyat A (No.14)	10YR 5/1	10YR 3/2	10YR 7/1
Ladang Rakyat A (No.15)	10YR 5/1	10YR 3/2	10YR 6/1
Ladang Rakyat A (No.31)	10YR 5/1	10YR 2/1	10YR 3/1
Ladang Dovenby (No.14)	10YR 5/1	10YR 4/3	10YR 6/4
Ladang Dovenby (No.19)	10YR 5/1	10YR 3/2	10YR 6/3
Ladang Dovenby (No.24)	10YR 5/1	10YR 3/2	10YR 6/2
Ladang Rakyat B (No. 3)	10YR 4/3	10YR 3/3	10YR 3/1
Ladang Rakyat B (No. 5)	10YR 4/3	10YR 3/3	10YR 6/2
Ladang Rakyat B (No. 7)	10YR 4/3	10YR 3/3	10YR 4/4
Ladang Rakyat B (No. 20)	10YR 4/3	10YR 3/2	10YR 3/1
Ladang Dovenby (No. 29)	10YR 4/3	10YR 3/2	10YR 5/8

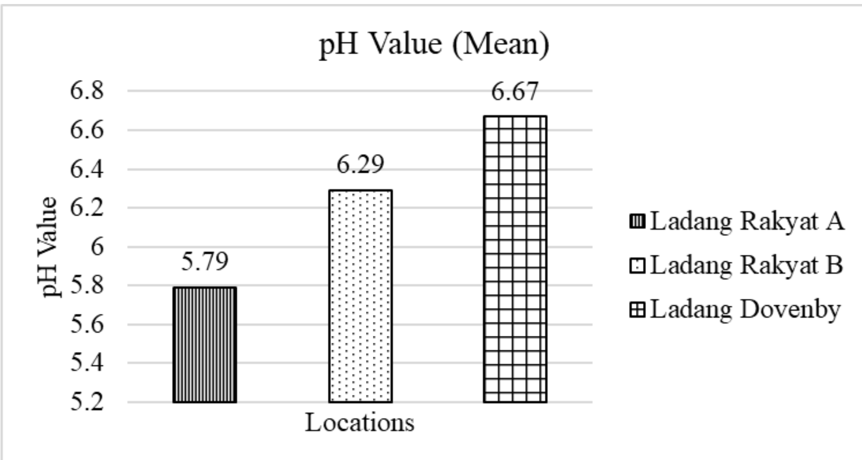

FIGURE 5: Comparison of pH mean value between soil from Ladang Rakyat A, Ladang Rakyat B and Ladang Dovenby

TABLE 3. Tamhane's Post Hoc test for pH analysis

Location comparison for pH analysis	Value of p for Tamhane's Post Hoc test
Ladang Rakyat A – Ladang Rakyat B	<0.001
Ladang Rakyat A – Ladang Dovenby	<0.001
Ladang Rakyat B – Ladang Dovenby	0.002

results from this study, when organic matter composition and iron removal are unable to implement to soil sample, ashing is still a better option for colour discrimination compared to moistening.

pH

Based on research conducted at Pathumthani, Thailand (Sahapatsombut et al. 2007) and Benin City, Nigeria (Ilori et al. 2014) suitable pH for optimum growth of oil palm is within the range of 4-6 which is in slight to moderately acidic. Agricultural soils such as oil palm soils in this case prone to acidification as base cations including calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium ion (K^{+}) are failed to return to soil naturally when plants decomposed. It is transported away after harvest instead which lead to acidification of soil gradually (Ashman & Puri 2002). The pH value range from this study is slightly higher than previous studies (Table 6). This is because the type of soil sample used in this research is topsoil which is more significant in forensic as it can be trace element that may adhere to personal belongings. This is confirmed by Ilori

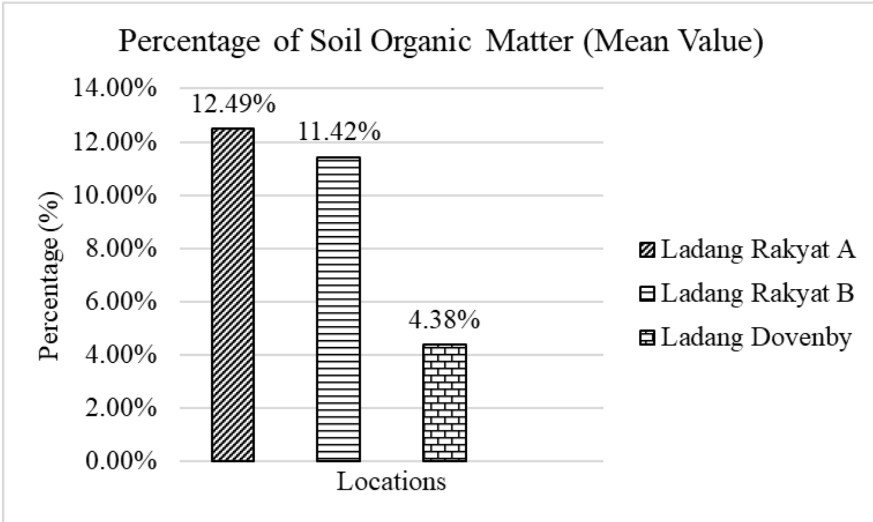

FIGURE 6: Comparison of percentage of SOM mean value between Ladang Rakyat A, Ladang Rakyat B and Ladang Dovenby

TABLE 4. Tamhane's Post Hoc test for determination of % of SOM

Location comparison for % SOM	Value of p for Tamhane's Post Hoc test
Ladang Rakyat A – Ladang Rakyat B	0.970
Ladang Rakyat A - Ladang Dovenby	0.000
Ladang Rakyat B - Ladang Dovenby	0.000

TABLE 5. Soil texture classification based soil particle size

Soil Texture Classification	Diameter range
Sand	0.05 - 2 mm
Very coarse	1 - 2 mm
Coarse	0.5 - 1 mm
Medium	0.25 - 0.5 mm
Fine	0.1 - 0.25 mm
Very fine	0.05 - 0.1 mm
Silt	0.002 - 0.05 mm
Clay	< 0.002 mm

et al. (2014) as they found that topsoil has higher pH value compared to subsurface layer of soil sample.

Furthermore, age of oil palm also causes variation in soil pH. Previous study by Gandaseca et al. (2014) shows that there is a significant difference between soil pH of mature oil palm and young oil palm. A recent study in Egbema, Nigeria further confirmed that soils around older oil palm have higher pH value compared to the younger oil palm (Okon et al. 2017). This is due to decomposition of huge amount of plant waste around older oil palm. This is coherent with this study as Ladang Rakyat A and Ladang Rakyat B have 2002 and 2003 oil palms with pH: 5.83 ± 0.04 and 6.29 ± 0.03 respectively, whereas Ladang Dovenby have oil palm ranging from year 1991 to 2016 (pH = 6.67 ± 0.03).

There are practices of using empty fruit bunches (EFB) as mulching material on top of oil palm soils (Teh et al. 2011). Application of EFB cause pH increment in topsoil due to soil reduction (anaerobic). Soil reduction will lead to reduction of cation such iron (III) oxide (Fe^{3+}) to iron (II) oxide (Fe^{2+}) and formation of hydroxide ion (OH^-) which will cause pH of soil to rise (towards alkaline) (Budianta et al. 2010). On top of that, the rate of release of potassium (K) is significantly higher compared to nitrogen (N) and phosphorus (P) during decomposition of EFB in which this basic cation causes rise in soil pH (Ping et al. 2012). Even though pH of soil in a way affected by management, but since the variation of pH still within a certain range, it is still suitable for forensic identification purposes.

TABLE 6. Summary of previous and this study on pH

Studied by	Location of oil palm plantation studied	pH value	Comment
Mutert 1999	Southeast Asia	< 5	Acidic
Sabrina et al. 2009	Rengam, Serdang, Jerangau, Bungor and Munchong	4.0 – 5.9	Acidic – slightly acidic
Ping et al. 2012	Semenyih (Selangor)	4 – 6.12	Acidic – slightly acidic
Paramananthan 2013	-	< 5.5	Acidic
Tan et al. 2014	Jengka 11 (Pahang)	< 5	Acidic
Gandaseca et al. 2014	Batang Igan (Sibu)	3.2 – 4.06	Very acidic - acidic
Ilori et al. 2014	South-South Zone (Nigeria)	4.58 – 5.85	Acidic – slightly acidic
Nur Aini et al. 2014	Teluk Intan (Perak)	3.82 – 4.55	Very acidic - acidic
Rozieta et al. 2015	New Labu Estate (Negeri Sembilan)	3.81	Very acidic
Faradina et al. 2016	Air Tawar (Perak)	4.8 – 5.8	Acidic – slightly acidic
Okon et al. 2017	Egbema (Nigeria)	5.52 – 6.61	Slightly acidic - very slightly acidic
This Study	Air Kuning and Sungai Siput (Perak)	5.79 – 6.70	Slightly acidic - very slightly acidic

SOIL ORGANIC MATTER (SOM)

Previous research showed that topsoil consist higher amount of SOM compared to underlying layers (Cox et al. 2000). Similar information is also stated in a guide by United States Department of Agriculture (USDA 1999). As the rate of root growth become higher, it contributes to formation and sustaining SOM (USDA 1999). The variation of SOM is determined by inputs (typically plant remnant) and outputs (generally mineralization to CO_2) (Nelson et al. 2013). SOM build-up also greatly influenced by quantity and quality of organic by-product, decomposition of microbial and soil capacity as SOM storage (Gandaseca et al. 2014). Since oil palm plantations are now mandatory to implement zero-burning technology, the oil palm plant residue such as the trunk and frond are buried into the ground. This causes mineralization to occur and vital nutrients are set back into soils (Shamshuddin & Daud 2011). This practice may cause accumulation of SOM on topsoil over the years.

In this study, there is no significant different in percentage of SOM between Ladang Rakyat A and Ladang Rakyat B because the age of oil palms in those estates are similar which is either planted on 2002 or 2003. However, Ladang Dovenby is significantly different from Ladang Rakyat A and Ladang Rakyat B because there is a huge variation between the ages of oil palms in Ladang Dovenby (1991-2016). This is because young oil palm have lower SOM as by-products are fewer compared to older palms (Sabrina et al. 2009). Since percentage of SOM is solely depends on management, hence it is not suitable for forensic soil identification as it could not represent a specific range of value that unique for oil palm soils.

CONCLUSION

For physical characteristics of topsoil samples from oil palm plantations, particle size >0.6 mm and within 0.18 - 0.6 mm have more uniform distribution compared to particle size <0.18 mm. The composition of particle size greater than 0.6 mm is within the range of 25.78 - 66.86% whereas for particle size between 0.6 mm and 0.18 mm is within 31.62 - 52.96% and 5.57-21.11% for particle size less than 0.18 mm. Colour varies with applied condition and the mode of colour after oven dried, moistened and ashed is greyish brown (10YR 5/2), very dark greyish brown (10YR 3/2) and light yellowish brown (10YR 6/4), respectively. For chemical characteristics, topsoil samples from oil palm plantations are slightly acidic with range of 5.79 – 6.70. Soil organic matter (SOM) composition in area studied approximately 20%, and less (in the range 3.29 - 20.48%).

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APPENDICES

APPENDIX A. Soil colours when oven-dried, moistened and ashed

		Colours of Oven Dried Soil	Colours of Moistened Soil	Colours of Ashed Soil
Ladang Rakyat A	1	10YR 4/1	10YR 2/1	10YR 3/1
	2	10YR 5/2	10YR 3/2	10YR 6/2
	3	10YR 4/2	10YR 2/2	10YR 3/1
	4	10YR 4/1	10YR 2/1	10YR 3/1
	5	10YR 5/3	10YR 4/2	10YR 7/2
	6	10YR 5/2	10YR 4/1	10YR 7/2
	7	10YR 4/2	10YR 2/2	10YR 4/1
	8	10YR 4/1	10YR 2/1	10YR 3/1
	9	10YR 5/2	10YR 3/2	10YR 7/1
	10	10YR 5/2	10YR 3/2	10YR 7/1
	11	10YR 5/1	10YR 4/2	10YR 7/1
	12	10YR 5/2	10YR 4/2	10YR 7/1
	13	10YR 4/2	10YR 2/2	10YR 4/1
	14	10YR 5/1	10YR 3/2	10YR 7/1
	15	10YR 5/1	10YR 3/2	10YR 6/1
	16	10YR 4/2	10YR 3/1	10YR 3/1
	17	10YR 5/2	10YR 3/2	10YR 7/1
	18	10YR 4/2	10YR 2/2	10YR 3/1
	19	10YR 4/1	10YR 3/2	10YR 5/1
	20	10YR 4/2	10YR 3/4	10YR 4/6
	21	10YR 4/1	10YR 3/1	10YR 5/1
	22	10YR 4/1	10YR 3/2	10YR 5/2
	23	10YR 5/2	10YR 4/2	10YR 6/2
	24	10YR 5/2	10YR 3/1	10YR 6/2
	25	10YR 5/2	10YR 2/2	10YR 3/1
	26	10YR 4/2	10YR 3/2	10YR 2/1
	27	10YR 4/1	10YR 2/2	10YR 3/1
	28	10YR 4/1	10YR 3/2	10YR 5/1
	29	10YR 3/2	10YR 2/1	10YR 2/1
	30	10YR 5/2	10YR 4/2	10YR 6/4
	31	10YR 5/1	10YR 2/1	10YR 3/1
	32	10YR 4/2	10YR 2/2	10YR 3/1
	33	10YR 5/3	10YR 4/3	10YR 5/6
	34	10YR 5/2	10YR 3/2	10YR 6/2
	35	10YR 5/2	10YR 3/2	10YR 3/1
Ladang Rakyat B	1	10YR 4/3	10YR 3/3	10YR 3/1
	2	10YR 4/2	10YR 2/2	10YR 3/1
	3	10YR 3/2	10YR 2/1	10YR 2/1
	4	10YR 4/4	10YR 3/6	10YR 4/6
	5	10YR 4/3	10YR 3/3	10YR 6/2
	6	10YR 4/1	10YR 2/1	10YR 6/1
	7	10YR 4/3	10YR 3/3	10YR 4/4
	8	10YR 4/1	10YR 3/2	10YR 5/3
	9	10YR 4/1	10YR 3/2	10YR 7/1
	10	10YR 4/1	10YR 3/2	10YR 2/1
	11	10YR 4/1	10YR 3/2	10YR 3/1
	12	10YR 3/1	10YR 4/2	10YR 2/1
	13	10YR 4/2	10YR 2/2	10YR 2/1
	14	10YR 5/3	10YR 3/2	10YR 6/4
	15	10YR 5/2	10YR 3/2	10YR 2/1
	16	10YR 5/4	10YR 3/6	10YR 4/2
	17	10YR 4/2	10YR 3/1	10YR 3/1
	18	10YR 5/3	10YR 3/3	10YR 4/4
	19	10YR 4/1	10YR 2/2	10YR 6/1
	20	10YR 4/3	10YR 3/2	10YR 3/1
	21	10YR 4/2	10YR 3/2	10YR 2/1
	22	10YR 5/2	10YR 3/3	10YR 3/1
	23	10YR 4/2	10YR 2/1	10YR 3/1
	24	10YR 4/2	10YR 2/1	10YR 3/1
	25	10YR 4/1	10YR 2/2	10YR 5/3
	26	10YR 5/3	10YR 3/3	10YR 3/1
	27	10YR 4/2	10YR 3/2	10YR 3/1
	28	10YR 4/2	10YR 2/2	10YR 3/1
	29	10YR 5/2	10YR 4/2	10YR 6/1
	30	10YR 6/2	10YR 4/3	10YR 6/3
Ladang Dovenby	1	10YR 5/2	10YR 2/1	10YR 7/2
	2	10YR 5/3	10YR 4/3	10YR 6/4
	3	10YR 6/3	10YR 5/3	10YR 6/8
	4	10YR 5/2	10YR 3/4	10YR 6/4
	5	10YR 6/2	10YR 5/3	10YR 7/4
	6	10YR 6/3	10YR 4/3	10YR 6/6
	7	10YR 5/3	10YR 5/4	10YR 5/8
	8	10YR 5/2	10YR 4/3	10YR 5/8
	9	10YR 5/3	10YR 4/3	10YR 6/4
	10	10YR 6/2	10YR 3/3	10YR 6/4
	11	10YR 5/3	10YR 5/4	10YR 5/8
	12	10YR 5/3	10YR 5/6	10YR 5/8
	13	10YR 5/2	10YR 4/3	10YR 6/4
	14	10YR 5/1	10YR 4/3	10YR 6/4
	15	10YR 6/1	10YR 5/2	10YR 7/2
	16	10YR 5/2	10YR 4/3	10YR 6/4
	17	10YR 5/3	10YR 3/6	10YR 5/8
	18	10YR 5/2	10YR 4/3	10YR 4/1
	19	10YR 5/1	10YR 3/2	10YR 6/3
	20	10YR 6/2	10YR 4/4	10YR 6/8
	21	10YR 6/2	10YR 5/3	10YR 6/6
	22	10YR 5/2	10YR 3/2	10YR 6/8
	23	10YR 6/2	10YR 4/3	10YR 6/4

24	10YR 5/1	10YR 3/2	10YR 6/2
25	10YR 5/2	10YR 3/2	10YR 7/4
26	10YR 6/2	10YR 5/3	10YR 6/6
27	10YR 5/2	10YR 4/2	10YR 6/4
28	10YR 4/2	10YR 3/2	10YR 5/8
29	10YR 4/3	10YR 3/2	10YR 5/8
30	10YR 4/2	10YR 3/3	10YR 5/3
31	10YR 5/2	10YR 4/3	10YR 5/6
32	10YR 7/2	10YR 5/3	10YR 7/6

APPENDIX B: Colour description based on Munsell Colour Book

Colour code based on Munsell Colour Book	Colour Name
2/1	Black
2/2	Very dark brown
3/1	Very dark grey
3/2	Very dark greyish brown
3/3	Dark brown
3/4	Dark yellowish brown type 1
3/6	Dark yellowish brown type 2
4/1	Dark grey
4/2	Dark greyish brown
4/3	Brown type 1
4/4	Dark yellowish brown type 3
4/6	Dark yellowish brown type 4
5/1	Grey type 1
5/2	Greyish brown
5/3	Brown type 2
5/4	Yellowish brown type 1
5/6	Yellowish brown type 2
5/8	Yellowish brown type 3
6/1	Grey type 2
6/2	Light brownish grey
6/3	Pale brown
6/4	Light yellowish brown
6/6	Brownish yellow type 1
6/8	Brownish yellow type 2
7/1	Light grey type 1
7/2	Light grey type 2
7/4	Very pale brown type 2
7/6	Yellow

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