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ANALYSIS OF SEASONAL SOIL ORGANIC CARBON CONTENT AT BUKIT JERIAU FOREST, FRASER HILL, PAHANG

(Analisis Kandungan Karbon Organik Tanah Secara Bermusim Di Hutan Bukit Jeriau, Fraser Hill, Pahang)

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Abstract

Soil carbon is the carbon held within the soil, primarily in association with its organic content. The total soil organic carbon study was determined in a plot at Bukit Jeriau forest in Bukit Fraser, Pahang, Malaysia. The aim of this study is to determine the changing of soil organic carbon between wet season and dry season. Soil organic carbon was fined out using titrimetric determination. The soil organic carbon content in wet season is 223.24 t/ha while dry season is 217.90 t/ha. The soil pH range in wet season is between 4.32 to 4.45 and in dry season in 3.95 to 4.08 which is considered acidic. Correlation analysis showed that soil organic carbon value is influenced by pH value and climate. Correlation analysis between clay and soil organic carbon with depth showed positively significant differences and clay are very much influenced soil organic carbon content. Correlation analysis between electrical conductivity and soil organic carbon content showed negative significantly difference on wet season and positively significant different in dry season.

Keywords: organic carbon, Fraser's Hill, forest, soil

Abstrak

Karbon tanah adalah nama generik bagi karbon yang wujud di dalam tanah, terutamanya dalam pencampuran kandungan organiknya. Satu kajian kandungan karbon organik di dalam tanih telah ditentukan di satu plot berukuran 1 hektar persegi di Hutan Simpan Bukit Jeriau, Bukit Fraser, Pahang, Malaysia. Tujuan kajian ini adalah untuk menentukan perbezaan kandungan karbon organik dalam tanah antara musim basah dan musim kering. Kandungan karbon organik ditentukan dengan menggunakan kaedah pentitratan.Jumlah kandungan karbon organik pada musim basah adalah sebanyak 223.24 t/ha manakala pada musim kering pula sebanyak 217.90 t/ha. Julat pH pada musim basah adalah 4.32 hingga 4.45 manakala pada musim kering adalah dari 3.95 hingga 4.08, dalam lingkungan berasid. Nilai pH pada musim kering mengalami penurunan. Analisis korelasi mendapati nilai pH dan iklim memberi kesan kepada kandungan karbon organik. Ujian korelasi antara lempung dengan kandungan karbon organik menunjukkan terdapat pebezaan signifikan positif. Ini menunjukkan kandungan lempung mempengaruhi kandungan karbon organik dalam tanih. Ujian korelasi kekonduksian elektrik dengan kandungan karbon organik menunjukkan perbezaan signifikan yang negatif pada persampelan musim basah manakala perbezaan signifikan positif pada musim kering.

Kata kunci: karbon organik, Bukit Fraser, hutan, tanih

Introduction

Organic are the terms use to describe the materials that associated with or derived from living organisms. The amount of organic matter in soil is often used as an indicator of the potential sustainability in a soil system. Soil organic matter are playing important part in nutrient cycle and repairing soil structure. Organic carbon in soil is important to ensuring good health in soil environment and critical in supplying the needs of the ecosystem [1,2]. Recently, research on soil organic carbon becoming important because of terrestrial organic carbon is critical factor to understanding carbon emission in which can causing climate change [3]. Organic carbon in soil are part of soil organic component, including others important elements such as hydrogen, oxygen and nitrogen. Organic in soil is derived from plants and animals that gradually decomposes. Soils constitute a significant reservoir of carbon (C) in both organic and mineral forms and can play an important global role, by mitigating or contributing carbon to the atmosphere [4,5]. Globally, soils contain more than two thirds of the total C stored in vegetation and almost twice the amount in the atmosphere while forest soils (including peaty soils) contain approximately 69 % of the total forest C pool [6]. With a small change in soil organic carbon, it can show a significant change for CO2 in atmosphere [7]. Carbon absorbance into the soil is a way that can decrease carbon accumulation in atmosphere which can lower the risks of climate changes. From that, the result show where soil organic carbon is very important to predict the effects and brings on global environment [8,9]. Field survey are a good ways to evaluate soil organic carbon including in the high altitude area such as Fraser Hill.

Carbon stored form the organic carbon in soil is highly sensitive to land use changes [10,11]. Organic carbon contain in soil are decrease with decreasing of organic matter inputs, while it increasing in organic carbon oxidation cause of aggregates disruption, and increasing the aeration. Many factors can indicate the stabilization of organic carbon in soil, the important factors are clay content, pH, hydrology, climate, and organic matter inputs. Some of these factors are fixed and depended on soil characteristics while some are depended on climate and land use management. Soil organic carbon storage are controlled by balanced from input from vegetation and decomposition output [12,13]. Organic carbon storage in soil are high in high altitude are because of high in carbon concentration (organic carbon per area) [14]. With unique climate and less human activity, Fraser Hill are ideal place to run a research on determine the soil organic carbon for the higher altitude area. Research on soil organic carbon changes are important for us to understand the relationship of its content in forest and their changes effect on global in the future [15].

Materials and Methods

Study area

Fraser Hill is very popular as a highland vacation and situated on 1500 m from sea level. This area is located on Titiwangsa range in Peninsular Malaysia which is formed by igneous formation activities from late Triassic to early Jurassic [2,15]. Annual rainfall distribution is 2624 mm with average 208 wet days. The area receives 20mm to 410mm of rainfall each month, typically low during the first quarter, and very high during the last quarter of the year. The temperature is cool, ranging from 18 °C – 22 °C annually with high humidity ranging from 85 – 95 % every month. The surrounding vegetation is lower montane forest [16]. Study site is one hectare plot located in Jeriau Forest, Fraser Hill, Pahang (Figure 1).

Soil samplings were done on one hectare plot (100m x 100m) where it has been divided into 9 subplots. To represent both dry and wet season, the soil sample was taken once for each season. The dry and wet season was determined using annual average rainfall at the nearest station and Malaysia annual rainfall data. Soil samples were taken from each subplot (Figure 2) by profile deep from 0 – 20 cm, 20 – 40 cm, 40 – 60 cm, 60 – 80 cm, and 80 – 100 cm. Research plot were located at 03°43’ 33.5” N, 101° 43’ 076” E to 03° 43’ 34.3” N, 101° 43’ 07.0” E and 03° 43’ 32.7” N, 101°43’ 05.6” E to 03° 43’ 32.9” N, 101°43’ 06.3” E. Each soil sample was taken to laboratory to be air dried and sieved using 2 mm sieve. Samples were then ready for analysis.

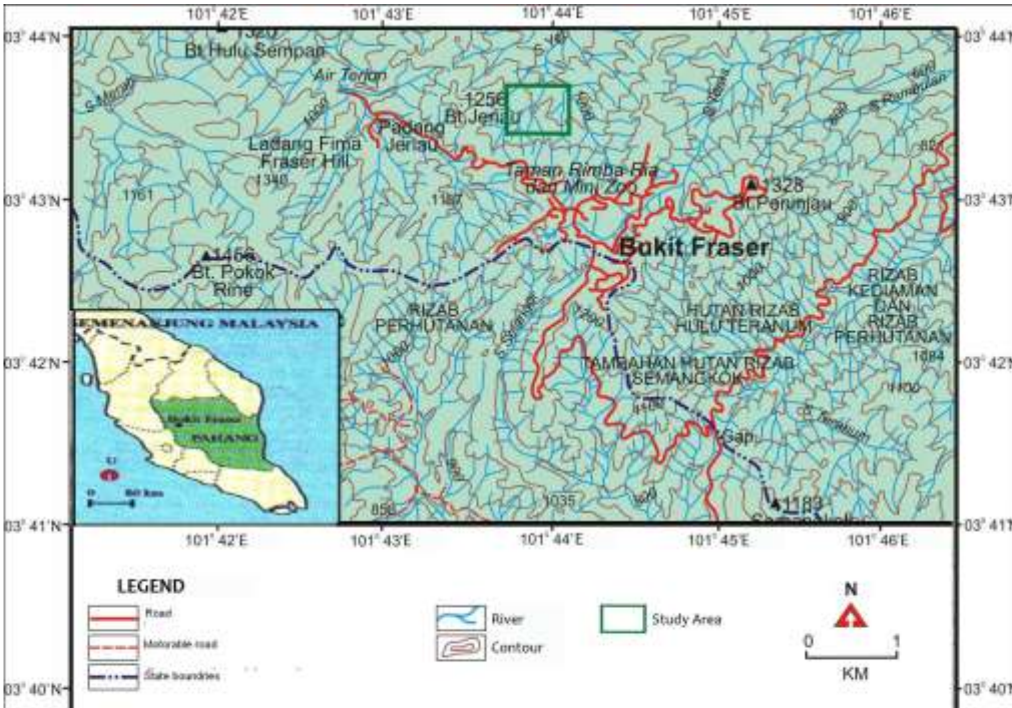

Figure 1. The map of study area

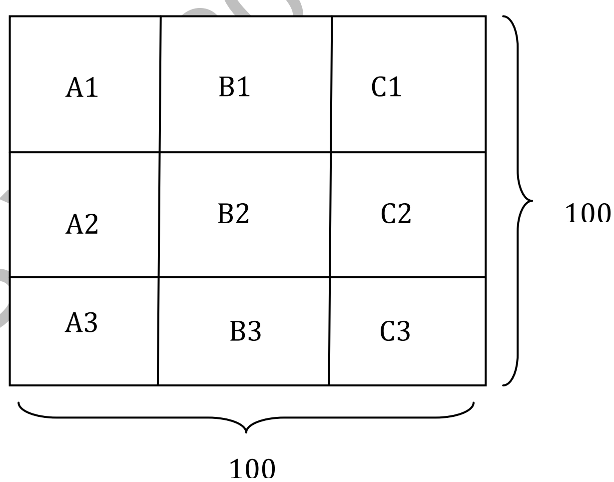

Figure 2. Research plot and subplots

Soil particle size distribution

20g soil are inserted into 600 ml beaker. Then, 50 ml of hydrogen peroxide (H^2O^2 - 30vol.) are pouring into it and heated on the sand bath with the temperature 60 – 70 °C until the mixture become less than 100 ml. Then, samples were transferred into Erlenmeyer flask and 5% sodium hexametaphosphate (20 ml) were added before shaking it in a period of 2 hour on reciprocating shaker. Then, the samples were transferred into 1000 ml beaker with the adding of water. Sub-sample size < 20µm and < 2µm were collected using pipette. The remaining samples were transferred into 600 ml beaker and the samples are slowly being washed until it's clear. The remaining was inserted into oven overnight at 105 °C. The samples when through sieved to determine the size and weighed to determine the soil particles distributions.

Measurement of pH and conductivity

Determinations of pH were using soil: water ratio of 1:1.2.5 [17]. pH value were read with pH meter that has been calibrated [18]. Soil electrical conductivity was determined using saturated gypsum extract. The remaining of filtered of mixtures were determined using conductivity meter which has been calibrated.

Determination of organic carbon content

Soil organic carbon was determined using Walkley & Black method [19]. An amount 0.5g soil sample were weighed and inserted into 500 ml Erlenmeyer flask. Then, 10 ml of Potassium Dichromate, 1.0 N $K_2Cr_2O_7$ were inserted and shake to mix it. Then, 20 ml sulphuric acid, H_2SO_4 (98 %) was poured into the mixture. The mixtures were left for 30 minutes to cool it. After that, 3 g of sodium fluoride (NaF) were added with 100 ml of distilled water. Ten drop of ferroin indicator were added which made the mixtures turned into orange solution. The mixtures were titrated with 0.5 N ammonium sulphate, until it turned into bright green [18]. The totals of FAS were recorded. The same operations were used to determine blank value with no sample was added. The formula to calculate the content of organic carbon in soil expressed as equation 1 below:

$$\text{Carbon content (KC)} = B \times A \times D \times C \tag{1}$$

where as KC is define as carbon content in ton, B is define as soil bulk density, (g^{cm-3}), A is define as area (m^2), D is define as soil depth (m) and C is percentage (%) of carbon organic.

Results and Discussion

Soil particle size distributions in study area were dominated by sandy and clayey soil (Table 1). Sand content on soil surface (0 – 20cm) were range from 39 % to 56 % with average value is 49 %. Soil texture becoming more sandy and less clayey with the increasing the depth. With sandier texture, water movements are high compare to clayey texture. According to Bationo and Buerkert [20], clay and silt type play an important role in the stabilization of organic compounds and small variations in soil texture could have large effects on soil organic carbon. With increasing clay content, it can decreased carbon output because of its stabilization effect on soil organic carbon.

Table 1. Soil particles size distribution

Sample	Depth (cm)	Sand (%)	Clay (%)	Silt (%)	Texture
A1	0 – 20	45	36	19	Sandy caly
	20 – 40	49	30	22	Sandy clay loam
	40 – 60	48	24	29	Sandy clay loam
	60 – 80	47	18	35	Loam
	80 – 100	64	11	25	Loamy sand
A2	0 – 20	48	34	18	Sandy clay loam
	20 – 40	53	32	15	Sandy clay loam
	40 – 60	59	27	14	Sandy clay loam
	60 – 80	69	15	16	Loamy sand
	80 –100	66	13	21	Loamy sand

Table 1 (cont'd). Soil particles size distribution

Sample	**Depth (cm)**	**Sand (%)**	**Clay (%)**	**Silt (%)**	**Texture**
A3	0 – 20	54	36	10	Sandy clay
	20 – 40	57	14	29	Loamy sand
	40 – 60	71	10	19	Loamy sand
	60 – 80	71	8	21	Loamy sand
	80 –100	72	8	20	Loamy sand
B1	0 – 20	42	39	19	Silty clay loam
	20 – 40	44	40	16	Silt
	40 – 60	51	32	17	Sandy clay loam
	60 – 80	53	27	19	Sandy clay loam
	80 –100	51	23	27	Sandy clay loam
B2	0 – 20	54	36	10	Sandy clay
	20 – 40	49	36	16	Sandy clay
	40 – 60	47	37	16	Sandy clay
	60 – 80	52	37	11	Sandy clay
	80 – 100	59	32	10	Sandy clay loam
B3	0 – 20	39	36	26	Sandy clay
	20 – 40	41	40	19	Sandy clay
	40 – 60	46	35	19	Sandy clay loam
	60 – 80	49	32	20	Sandy clay loam
	80 – 100	52	27	21	Sandy clay loam
C1	0 – 20	54	35	12	Loam
	20 – 40	49	31	19	Loam
	40 – 60	54	30	17	Loamy sand
	60 – 80	65	14	21	Sandy clay loam
	80 –100	78	7	15	Loamy sand
C2	0 – 20	46	35	19	Loam
	20 – 40	52	32	16	Loamy sand
	40 – 60	57	29	14	Loamy sand
	60 – 80	66	16	18	Loamy sand
	80 – 100	79	5	15	Loamy sand
C3	0 – 20	56	33	11	Loamy sand
	20 – 40	58	16	26	Sandy clay loam
	40 – 60	71	10	19	Sandy clay loam
	60 – 80	71	8	21	Sandy clay loam
	80 – 100	70	11	19	Loamy sand

According to Table 2, soil organic carbon content were decreasing with increasing soil depth with the highest soil organic carbon content in depth of 0 – 20 cm for both seasons. The percentage of organic carbon content in wet seasons were higher than dry season at the depth 0 – 20 cm and 20 – 40 cm, while at the depth 40 – 60 cm, 60 – 80 cm, and 80 – 100 cm the percentage of soil organic carbon were higher in dry season. These differences were attributed to differences in belowground allocation of biomass among vegetation types, and tree dominated systems had higher inputs of organic matter than other types at the surface of the soil [21]. There was obvious changing in soil organic carbon concentration until 60 cm depth. After 60 cm depth, soil organic carbon concentration slowly reduces until 100 cm depth. The difference in soil organic carbon concentration at this depth is due to vegetation and hydrology [22]. Water moving downwards carries dissolved organic carbon to deeper soil horizons, where it is preserved from complete mineralization, gradually the transported compounds are reabsorbed to soil particles and contribute to carbon storage deeper in the soil profile. The difference of soil organic carbon content between both seasons is 5.33t/ha (Figure 3).

Table 2. The average soil organic carbon content with depth

Depth (cm)	**% OC Wet season**	**Bulk density (gm^{-3})**	**TOC, (t/ha)**	**% OC Dry season**	**Bulk density, (gm^{-3})**	**TOC, (t/ha)**
0 – 20	4.93	1.04	102.54	4.18	1.03	86.38
20 – 40	2.95	1.04	61.36	2.78	1.03	57.41
40 – 60	1.31	1.03	26.99	1.72	1.03	35.44
60 – 80	1.05	1.04	21.84	1.14	1.03	23.53
80 –100	0.51	1.03	10.51	0.74	1.02	15.14
		Total	223.24		Total	217.90

% OC = percentage of organic carbon in soil; TOC = Total organic carbon

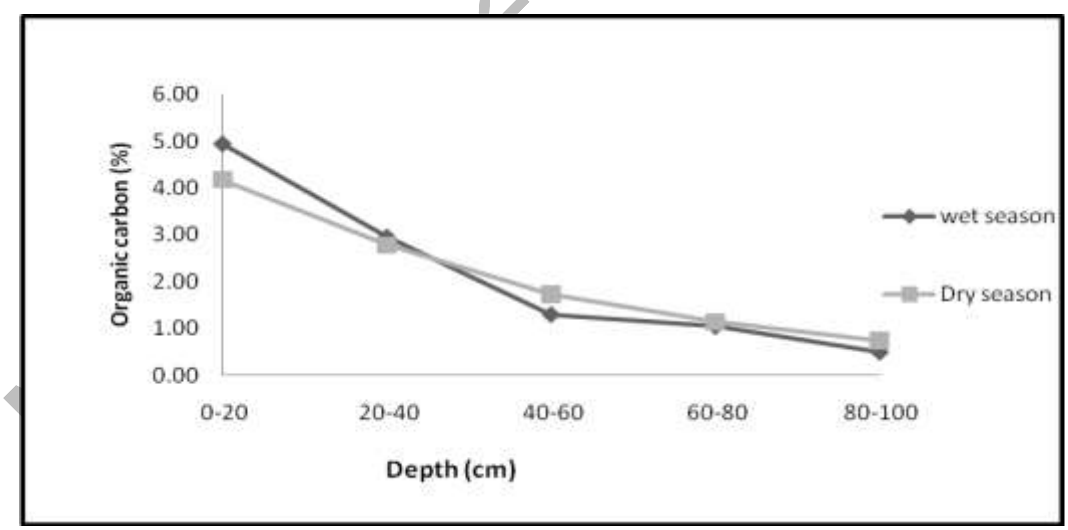

Figure 3. Seasonal soil organic carbon content with depth

Correlation analysis between clay and organic carbon content were significant different on both seasons. Wet season were positively significant at 0.01 (n = 30, r = 0.594**), while on dry season also positively significant at 0.01 (n = 45, r = 0.688**). Soil organic carbon concentration were high at upper soil profile and become lesser at the deep profile. Particle size distribution analysis showing clay content increase with depth. Carbon content and status in the soil are closely associated with clay and silt contents and clay type, which influences the stabilization of organic carbon [20]. Increasing clay content can provide the stabilization of organic carbon in soil and slowing down decomposition process by microbes [11,23]. In this study, soil organic carbon concentrations were high at high clay area. High clay content can increase plant productivity through water holding capacity in which adding carbon input into the soil [24].

Figure 4 show the value of pH versus depth on both seasons. pH values were stable on both seasons at all station. On dry season pH value were ranging from 3.95 – 4.08 and during wet season it ranging from 4.32 –4.45. Relatively, pH values were lower at depth 0 cm to 40 cm. From 40 cm to 100 cm deep, the changing values were low on both seasons. pH value are related to decomposition of organic matter in which it can affect pH value and also increase organic carbon content in soil. This is also related with the low organic carbon concentration in deeper soil profile, meaning soil organic carbon content increase with decreasing pH value. Correlation analysis between pH and soil organic carbon on dry season were negatively significant at 0.015 (n = 45, r = - 0.378*). There is no significantly different on wet season.

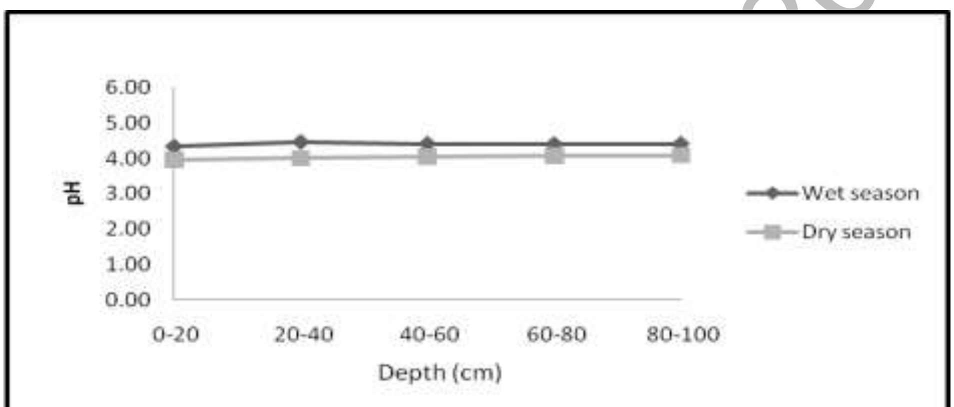

Figure 4. An average of pH value in soil samples

Electrical conductivity (Figure 5) values were stable at every depth on both seasons. During wet season, the highest electrical conductivity was measured at 0 – 20 cm deep with the value 2.65mS/cm and lowest value was 2.52mS/cm at 60 – 80cm deep. During the dry season, highest electrical conductivity value was 2.56mS/cm at 0 – 20 cm deep and at depth of 40 – 60cm the lowest value recorded at 2.33m^{S}/cm. Electrical conductivity in soil are influenced by soil texture (especially clay), water content and soil water holding capacity, dissolved ion in soil capillary. Soil electrical conductivity value increased with increasing of clay content and water content. According to Officer et. al. [25], the soil zone with high electrical conductivity value are high in clay and organic material content. Correlation analysis between electrical conductivity and soil organic carbon content on wet season showing significantly positive at 0.05 (n = 45, r = 0.315*) and on dry season were significantly negative at 0.01 (n = 45, r = -0.583**). It showed that electrical conductivity influenced by the value of soil organic carbon content. Correlation analysis between electrical conductivity with pH showing negatively significant on dry season at 0.05 (n = 45, r = -0.353*) but on wet season, there is no significantly different. It means on dry season, salt content in soil have small influence on pH value but not in wet season.

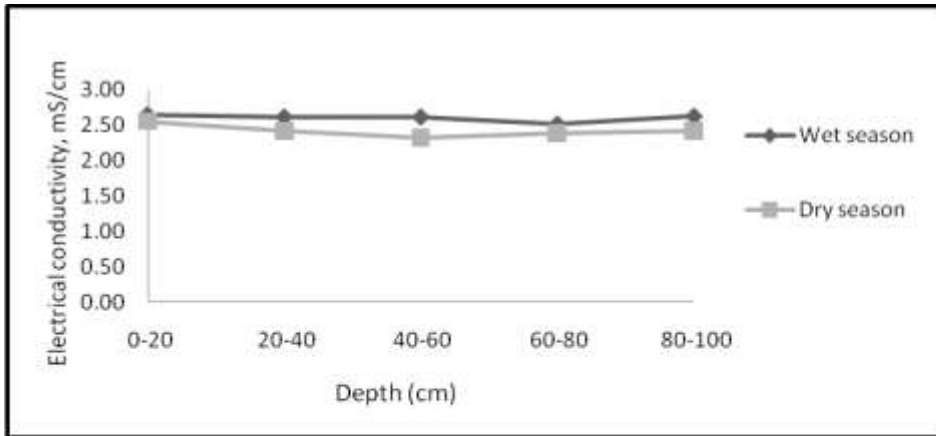

Figure 5. Measurement of electrical conductivity in soil samples

Conclusion

Soil organic carbon content were slightly higher in wet season compared to dry season with the different value of 5.34 t/ha. Soil organic carbon content is decreasing with depth on both seasons. The value of soil organic carbon decreasing drastically from high organic matter in higher soil profile and lower in deeper soil profile. pH value in dry season were acidic than wet season. Soil electrical conductivity values were stable and not much significantly different on both seasons. The average soil electrical conductivity value on wet season is 2.61m^S/cm and during dry season is 2.42m^S/cm.

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References

1. Toriman, M.E, Gasim, M. B., Yusop, Z., Shahid, I., Mastura, S. A. S., Abdullah, P., Jaafar, M., Abd Aziz, N. A., Kamarudin, M. K. A., Jaafar, O., Karim, O., Juahir, H. and Jamil, N. R. (2012). Use of 137Cs activity to investigate sediment movement and transport modeling in river coastal environment. *American Journal of Environmental Sciences*, 8 : 417 – 423.
2. Kamarudin, M. K. A., Toriman, M. E., Rosli, M. H., Juahir, H., Azid, A., Mohamed Zainuddin, S. F., Abdul Aziz, N. A. and Sulaiman, W. N. A. (2015). Analysis of meander evolution studies on effect from land use and climate change at upstream reach of Pahang River, Malaysia. *Mitigation and Adaptation Strategies for Global Change*, 20:1319 – 1334.
3. Velmurugan, A., Gopal K., Dadhwal, V. K. Kumar, S., Swarnam, T. P. and Saha, S.K.(2009). Harmonizing soil organic carbonestimates in historical and current data. *Current Science*, 97(4): 12 – 22
4. Azid, A., Che Hasnam, C. N., Juahir, H., Amran, M. A., Toriman, M. E., Kamarudin, M. K. A., Mohd Saudia, M. S., Gasim, M. B. and Mustafa, A. D. (2015). Coastal erosion measurement along Tanjung Lumpur to Cherok Paloh, Pahang during the northeast monsoon season. *Jurnal Teknologi*, 74 (1): 27 – 34.
5. Kamarudin, M. K. A., Toriman, M. E., Sarifah A., S. M, Idris, M., Jamil, N. R. and Gasim, M. B. (2009). temporal variability on lowland river sediment properties and yield. *American Journal of Environmental Sciences*, 5(5): 657 – 663.
6. Zerva, A. and Maurizio M. (2005). Carbon stock changes in a peaty gluey soil profile after afforestation with Sitka spruce (Picea sitchensis). *Annals Forest Science*, 62: 873 – 880.
7. Thornley J. H. M. and Cannell, M. G. R. (2001). Soil carbon storage response to temperature: an hypothesis. centre for ecology & hydrology, Bush Estate, Penicuik, Midlothian, *UK Annals of Botany*, 87: 591 – 598.

8. Sahibin, A. R., Mohd. Nizam, M.S. and Izzat Hidayat, I. (2004/05). Physico-chemical characteristics of soil at Sg. Cheruai in the national park at Merapoh Pahang. *Journal Wildlife and Parks*, 22: 145 - 152.
9. Steinbeiss, S., Temperton, V. M. and.Gleixner, G. (2007). Mechanisms of soil carbon storage in experimental grasslands. *Biogeosciences Discuss.*, 4, 3829 – 3862.
10. Abdullah, N. M., Toriman, M. E., Md Din, H., Abd Aziz, N. A., Kamarudin, M. K. A., Abdul Rani, N. S., Ata, F. M., Saad, M. H., Abdullah, N. W., Idris, M. and Jamil, N. R. (2013). Influence of spatial and temporal factors in determining rainfall interception at dipterocarp forest canopy, Lake Chini, Pahang. *Malaysian Journal of Analytical Sciences*, 17 (1): 11 – 23.
11. Yuanhe, Y., Ngyun, F., Yanhong, T., Chengjun, J., Chengyang Z., Jinsheng H. and Biao Z. (2008). Storage, patterns and controls of soil organic carbon in the Tibetan grasslands. *Global Change Biology* 14: 1592 – 1599
12. Veldkamp, E., Becker, A., Schwendenmann, L., Clark. D. A, and Schult-Bisping. H (2003). Substantial labile carbon stocks and microbial activity in deeply weathered soils below a tropical wet forest. *Global Change Biology*, 9: 1171 – 1184.
13. Steinbeiss, S., Temperton, V. M. and Gleixner, G. (2007). Mechanisms of soil carbon storage in experimental grasslands. *Biogeosciences Discuss*, 4: 3829 – 3862.
14. D'bek-Szreniawska, M. and Balashov, E (2007). Seasonal changes in labile organic matter, mineral nitrogen, and N_2O emission in a loamy sand Orthic Luvisol cultivated under three management practices. *International Agrophysics* , 21: 127 – 132.
15. Zulfahmi, A. R., Jasni, Y., Sahibin, A. R. Gasim, M. B. and Ramlan, O. (2002). Preliminary survey of landslide occurrences along main road of gap-Fraser's Hill, Pahang. *Proceedings of the Regional Symposium on Environment and Natural Resources*, 1: 745 – 751.
16. Noraini M.T. (2002). The use of selected geo-materials for erosion and sediment control at Fraser's Hill. *Proceedings of the Regional Symposium on Environment and Natural Resources*, 1: 305 – 312.
17. Metson, A. J. (1956). Methods of chemical analysis for soil survey samples. Bulletin of the New Zealand Department of Industrial Research. No. 12.
18. Rowell, D.L. (1994). Soil science: method and applications. Singapore: Longman Singapore Publishers (Pte) Ltd.
19. Avery, B. W. and Bascomb, C. L. (1982). Soil survey laboratory methods. Soil Survey Technical Monograph No. 6. Harpenden.
20. Bationo A. and Buerkert A. (2001). Soil organic carbon management for sustainable land use in the Sudano-Sahelian West Africa. *Nutrient Cycling in Agroecosystems* 61:131 – 142.
21. Richard V. Pouyat, Ian D. Yesilonis Nancy E. Golubiewski. (2009). A comparison of soil organic carbon stocks between residential turf grass and native soil. *Urban Ecosyst*, 12:45 – 62
22. Reese, R. E. and Moorhead, K. K.. (1996). Spatial characteristics of soil pro:perties along an elevational gradient in a Carolina Bay wetland. *Soil Science Society American Journal*, 60: 1273 – 1277.
23. Zhuang, Q., Li, Q., Jiang, Y., Liang, W. and Steinberger, Y. (2005). Vertical distribution of soil organic carbon in agrosystems of Songliao Plain along a latitudinal gradient. *American-Eurasian Journal of Agriculture and Environment Science*, 2(2): 127 – 132.
24. Henry. M., Valentini. R., and Bernoux. M (2009). Soil carbon stocks in ecoregions of Africa. *Biogeosciences Discussions*, 6: 797 – 823.
25. Officer, S. J., Kravchenko, A., Bollero, G. A., Sudduth, K. A., Kitchen, N. R. and Wiebold. W. J. (2004). Relationships between soil bulk electrical conductivity and the principal component analysis of topography and soil fertility values. *Plant and Soil*, 258: 269 – 280.