PHYSICO-CHEMICAL PROPERTIES, CARBON DIOXIDE EMISSIONS AND CARBON STOCK IN PEAT SOIL USED FOR TURMERIC CULTIVATION AT KUALA LANGAT SELATAN, SELANGOR, MALAYSIA

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ABSTRACT. *Measurement of carbon dioxide emissions in peat soil was done in a turmeric cultivation area on August 2009 and January 2010 at Kampung Tumbuk Darat, Kuala Langat Selatan, Selangor. The objective of this research was to determine the quantity of CO_2 emissions from peat soil as well as the carbon stock that is stored in the peat soil. Other parameters that were investigated included soil pH, soil temperature, soil bulk density, soil organic carbon, soil fresh water content, organic matter, humic acid and fulvic acid content. A total of 30 carbon dioxide emission sampling points in rectangular grid arrangement was prepared in a survey plot of 1 hectare. The survey plot was further divided into sub-plots of size 20 m x 25 m. Soil samples were randomly taken at the depth of 0-15 cm to 50-65 cm using an auger. Sampling of CO_2 emissions was done using the static alkali absorption method (Kirita Method). The organic carbon content was determined using the Walkley-Black method, while the humic and fulvic acid content was determined using the basic molecule isolation method. Other soil properties were determined using standard methods of determination. The surface temperature of peat soil was between 28^oC and 30^oC. The bulk density of the area was as low as 0.20 g cm^{-3}. On the other hand, the soil fresh water content, soil organic matter, and peat soil humic acid was very high. The minimum quantity of CO_2 emissions in the peat soil on August 2009 and January 2010 was 40.92 ± 21.62 t CO_2 ha^{-1} yr^{-1} (467.10 ± 246.86 mg CO_2 m^{-2} hr^{-1}) and 41.51 ± 13.41 t CO_2 ha^{-1} yr^{-1} (473.86 ± 153.12 mg CO_2 m^{-2} hr^{-1}), respectively. Carbon stock for the month of August 2009 and January 2010, respectively was 297.70 t ha^{-1} and 456.60 t ha^{-1}. T test showed that there were significant ($p<0.05$) differences in many of the soil parameters such as the pH, water content and organic carbon. Correlation analysis showed that CO_2 is influenced by the organic matter, water content and temperature.*

KEYWORDS. *Humic and fulvic acid, CO_2 emissions, carbon stock, peat soil, turmeric*

INTRODUCTION

Carbon dioxide is a primary greenhouse gas with 60% contributing to the amount of greenhouse effect. Soil is a major source of carbon dioxide in the atmosphere. If there is an increased threat of global warming caused by greenhouse gas emissions, the reduction of carbon dioxide emissions originating from the soil is essential (Monika et al., 2002). Carbon dioxide is released from the soil through various processes, i.e. soil respiration, the evolution of carbon dioxide in the soil, and the outflow of carbon dioxide. The rate of carbon dioxide released into the atmosphere from the soil is controlled by the production rate of carbon dioxide in the soil (Raich & Shlesinger 1992). Good airflow in the soil optimizes the oxidation of organic matter by microbes and the release of excess carbon dioxide into the atmosphere. The nature of the carbon dioxide loss in the soil is seasonal and changes with different activities (Liikanen et al., 2006) and it depends strongly on factors such as the surrounding temperature, the type of soil, soil cavities, and soil water content (Chow et al., 2006;

Fenner et al., 2005; Silvola et al., 1996). Outflow of carbon dioxide from the Earth's surface into the atmosphere is biologically produced from plant roots and microbial respiration, with microbial respiration as the major contributor. Plant roots respiration contributes to the change of organic carbon acquisition in the soil, camouflaging the true role of soil respiration in global warming (Cheng et al., 2005; Kuzyakov, 2002a, 2002b). As the flow of carbon dioxide from the soil into the atmosphere has significant effects to global warming, many studies on the method of measuring soil respiration have been done. However, soil respiration is difficult to measure precisely because it deals with uncertainties in various methodologies, uses a large amount space, presence of temporary variables within the soil respiration, environmental factors and so on (Norman et al., 1997). This research paper discuss on the carbon dioxide emissions and carbon stock in peat soil planted with turmeric at Tanjung Tumbuk, Kuala Langat Selatan, Selangor, Malaysia.

MATERIALS AND METHODS

Study Area

The study area is located in Kampung Tumbuk Darat at Tanjung Tumbuk, Kuala Langat Selatan, Sepang. The type of soil is peat soil which has been used as an agricultural area for the cultivation of turmeric. Sampling was carried out during 20 to 21 August 2009 (Thursday and Friday) and 18 to 19 January 2010 (Monday and Tuesday). There was heavy rain during the days of sampling. The study site is located at coordinates 02°41'09.3"N and 101°35'18.1"E (Figure 1).

Figure 1: Location of study site at Kampung Tumbuk Darat,
Kuala Langat Selatan, Selangor (adapted from Jabatan Pemetaan Malaysia)

Sampling Of Carbon Dioxide

Thirty (30) sponges measuring 9.5 cm x 15 cm x 2 cm were prepared and placed in plastic containers of the same length and width (9.5 cm x 15 cm x 5 cm). The sponges were tied with a thread so that it sticks on the inside at the top of the plastic containers. A total of 40 mL of 2 N KOH was prepared and poured onto each sponge. The containers were closed immediately and tightly. Upon reaching the site, each cover of the containers was reopened and placed upside down on top of the soil at the selected sampling points. Three sampling for 'blank' was also performed in which the container lids were not opened and placed at random. After 24 hours, the plastic containers which were labelled CO_2 emissions sampling points were collected. All plastic containers were closed tightly and placed in a black plastic bag for laboratory analysis of the samples.

Analysis of Carbon Dioxide

Carbon dioxide (CO_2) content in the soil samples was determined using static alkali absorption method (Kirita, 1971). The sponge was removed from the container and squeezed into a beaker immediately to obtain a KOH solution containing CO_2 (sample A). A total of 5 mL sample was taken from the beaker and added with 3 point phenolphthalein indicator. This mixture was then titrated with 0.2 N HCl until the pink colour disappeared. After that, 3-methyl orange indicator point was added to the mixture. This new mixture was titrated with HCl until a light pink colour was obtained at the end point. Blank test (sample B) and KOH solution which was not used (sample C) for sampling was carried out using the same method (Kirita, 1971). During the course of this analysis the researcher needs to wear a mask to avoid inhalation of the carbon dioxide.

Soil Sampling and Analysis

Topsoil samples (0-15 cm) and sub-soil samples (50-65 cm) were collected using Dutch Auger. Soils collected were kept in a labelled plastic bag and transported to the laboratory. In the lab, the soil samples were dried in a room temperature by spreading them on a newspaper. Upon drying the soil samples were pounded and sieve to pass through 2 mm sieve opening. This 2 mm sieved soil is ready for analysis. Soil pH value was determined in distilled water with distilled water: soil ratio at 2.5: 1 and then determined using a pH meter (Mettler Toledo model Delta 320). The soil fresh water content and organic matter content was determined by gravimetric analysis (Tan, 2005). Soil temperature was determined by *in situ* method using a thermometer pushed at 10 cm depth. Organic carbon content was determined using Walkley and Black method (Walkley, 1947). Humic and fulvic acid content were determined using the basic molecular separation method (Tan, 2005). The bulk density was determined using the metal ring method (Patiram *et al.,* 2007). Data obtained were analysed using ANOVA, t-test, regression and correlation test in excel environment.

## RESULTS AND DISCUSSION

Soil Temperature

The mean soil temperature range of the five sampling points are between 28°C to 30°C (Figure 2) with an average and standard deviation of 29 ± 0.28°C. This value of mean temperature did not show any significant difference between the sampling stations (p> 0.05). This value is within the temperature interval as in the study of Fujii *et al.,* (1998) which reported that the soil temperature at the surface and subsurface is between 12°C to 33°C (0.15-0.5 m depth) and 13°C to 27°C (1.5-2.0 m depth) respectively. Temperatures that are too high can prevent microbial respiration caused by inactivity of biological oxidation systems (Monika *et al.*, 2002).
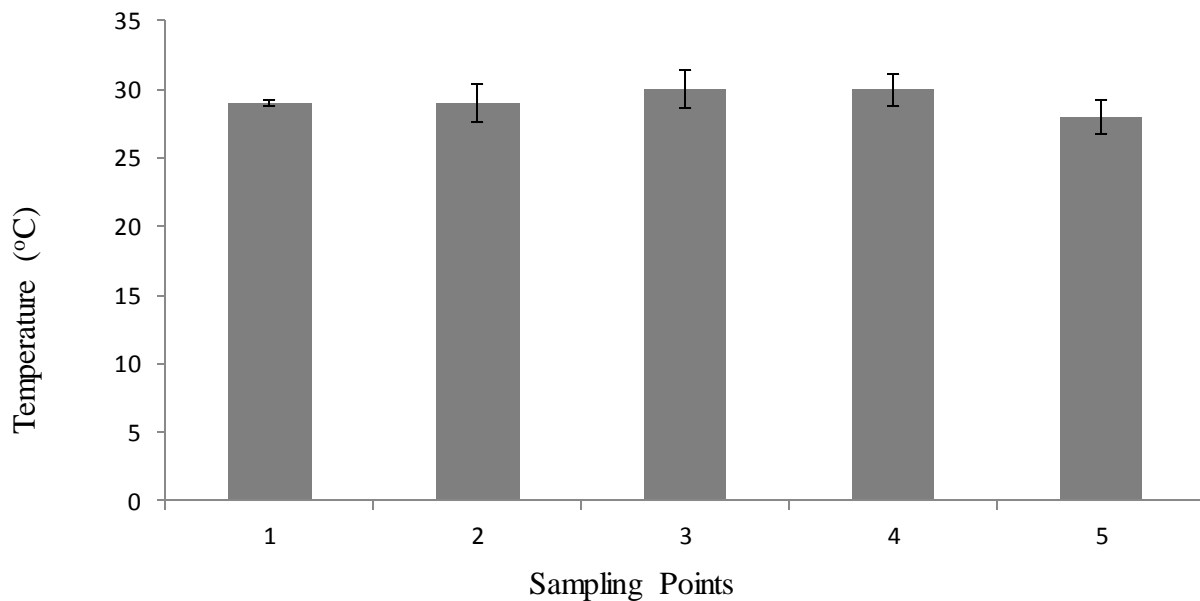
Figure 2: Mean (± standard deviation) soil temperature at the various sampling points

Soil pH

Mean range of soil pH observed at the sampling points at depth 0-15 cm is between 3.07 to 3.12 while the pH at a depth of 50-65 cm is 2.98 to 3.39 (Figure 3). The pH increases with depth at S1, S2 and S4, but decreases with depth at S3 and S5. However, ANOVA test shows that changes in pH between stations are not significantly difference (p>0.05). The pH value observed by month (Figure 4) shows a higher value in January compared to August. Paired t tests on soil pH showed a significant difference between the mean of August and January, with p = 0.000. In peat soil pH is influenced by the decomposition of organic matter directly by microorganisms into organic acids, carbon dioxide and water, thus creating carbonic acid (Kirschbaum, 1995). Acid interacts with calcium carbonate and magnesium carbonate in the soil to form dissolved bicarbonate and which result in acidic soil (Wu *et al.,* 2003). The soil was more acidic in August compared to the month of January due to heavier rain in August. When rainwater moves through the soil, the base cations such as calcium and magnesium would be leached and replaced at the adsorption sites by acid cations. In the rainy season or in areas with high rainfall the soil is usually more acidic (Guo & Gifford, 2002).
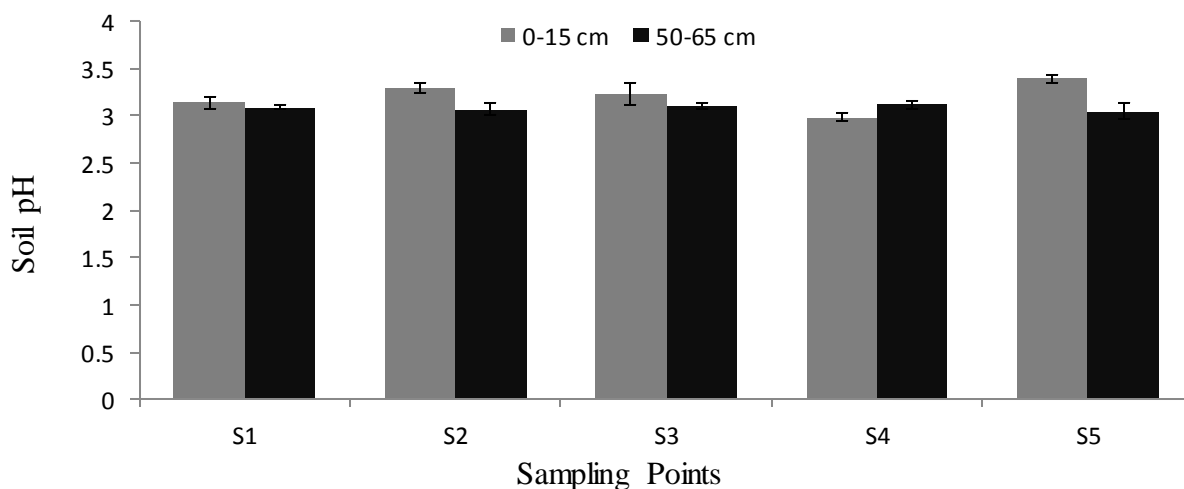

Figure 3: Mean (± standard deviation) soil pH with respect to sampling points and depths
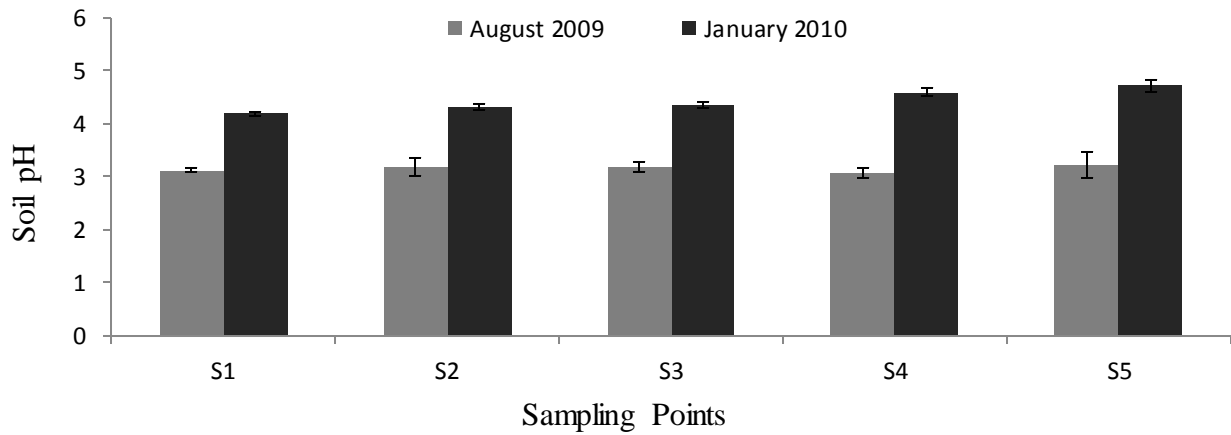
Figure 4: Mean soil pH of sampling points in August 2009 and January 2010

Soil Bulk Density

The range of soil bulk density was observed between 0.19 g cm^{-3} to 0.22 g cm^{-3} (Figure 5) with a mean and standard deviation 0.20 ± 0.000 g cm^{-3}. Paired t tests showed that the bulk density did not show significant differences in August and January sampling (p = 0.612). Low bulk density values at all sampling points showed that peat soil has high volume and cavity space. The high organic content leads to aggregated soil which causes the soil to become loose and lowering the bulk density of the soil (Lal, 2002).
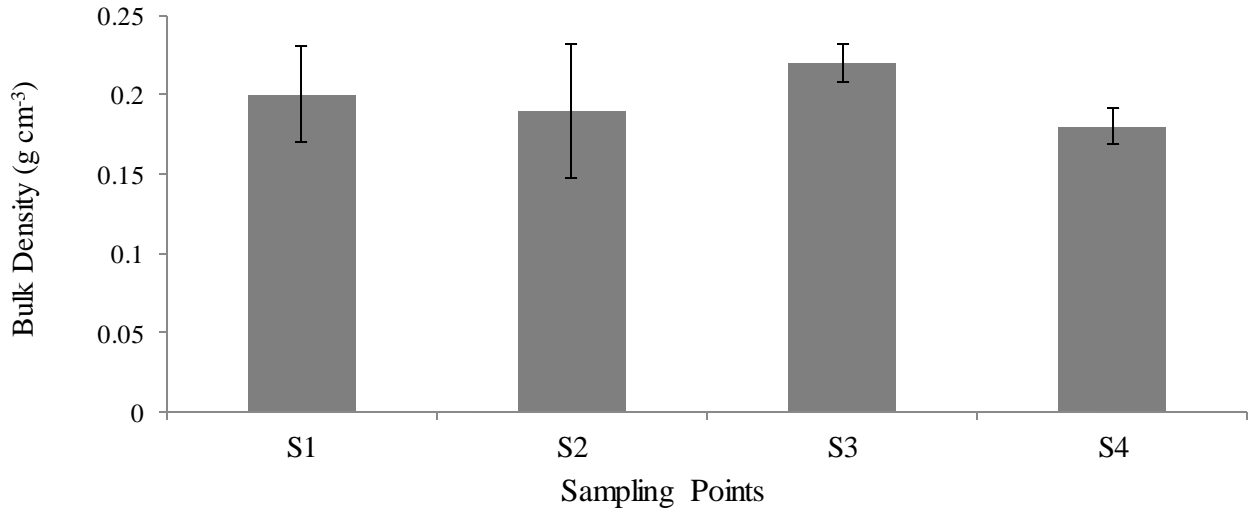
Figure 5: The mean (± standard deviation) bulk density of the various sampling point (sampling depth 0-15 cm)

Soil Water Content

Mean range of soil fresh water content recorded at all sampling points was between 73.58% and 80.57% at a depth of 0–15 cm (Figure 6). At a depth of 50-65 cm in the mean range of soil fresh water content was between 79.39% and 84.17%. Soil fresh water content showed significant differences with their depths. Figure 6 also shows an increase in the water content of the soil with depth for all sampling points. Peats soils have a high water level therefore the water content in the sub-soil are usually higher.
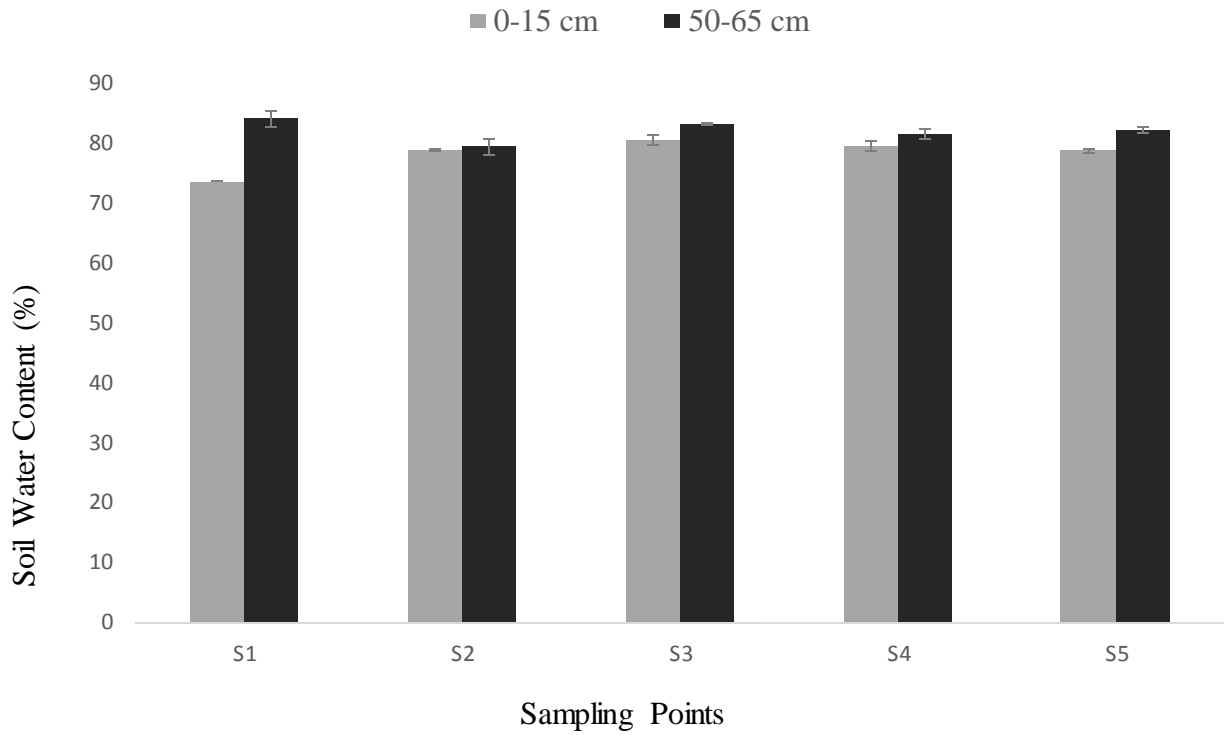
Figure 6: The mean (± standard deviation) water content with respect to sampling points and depths
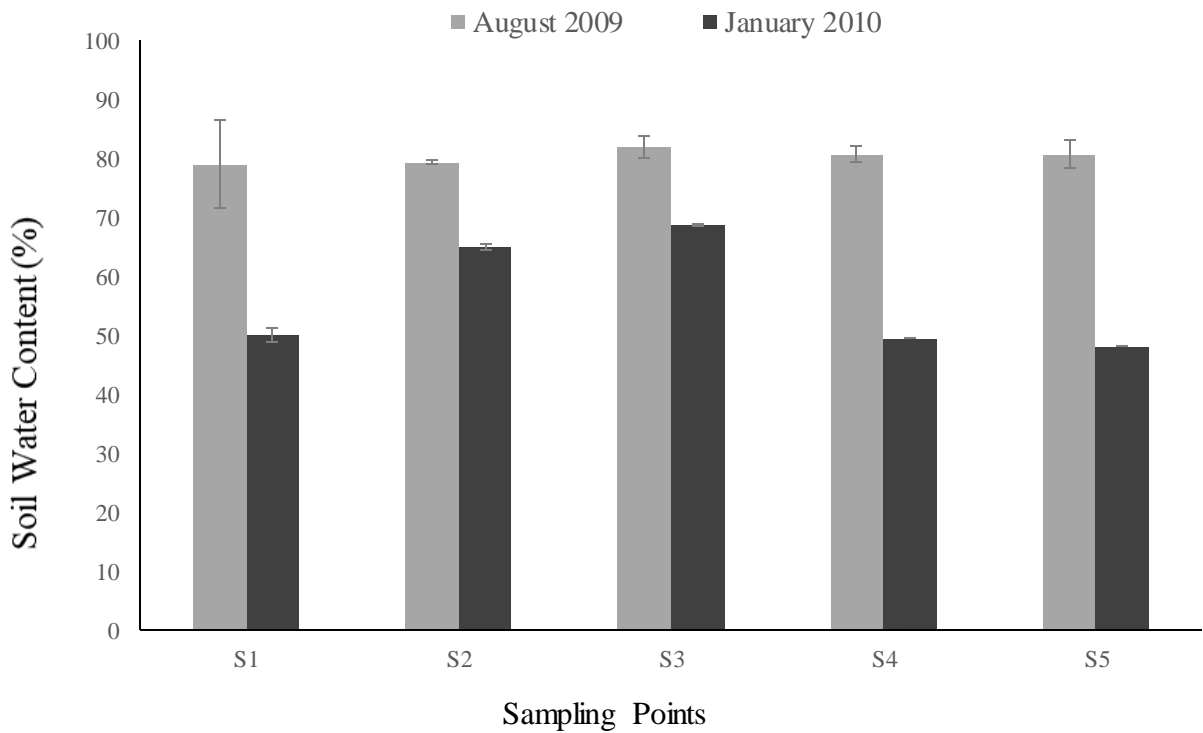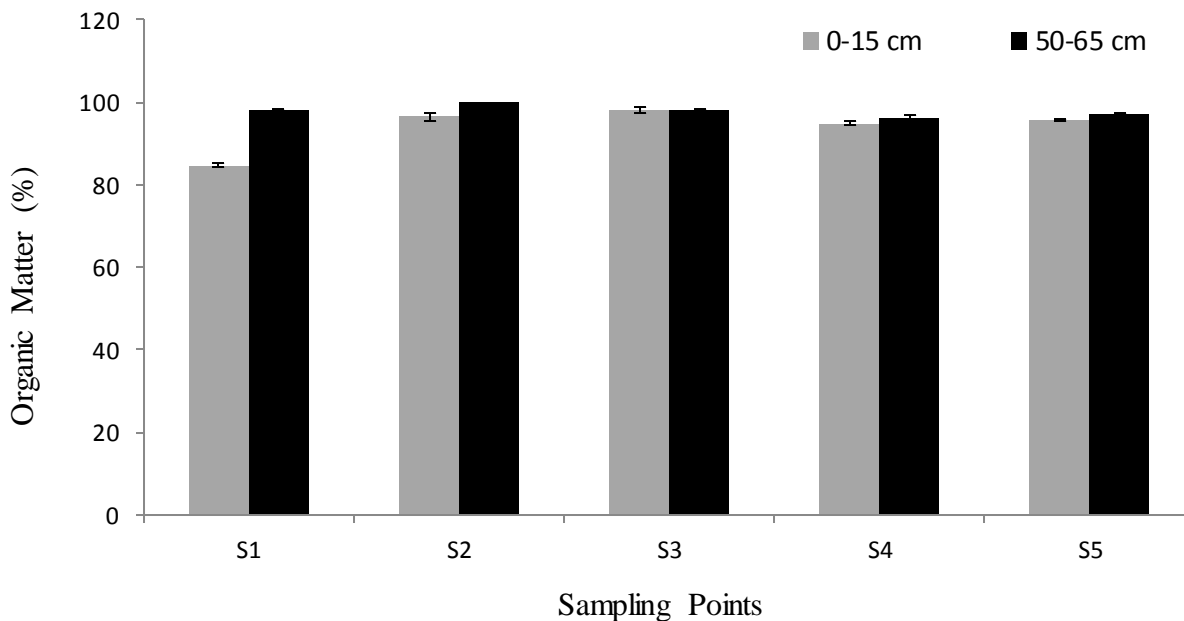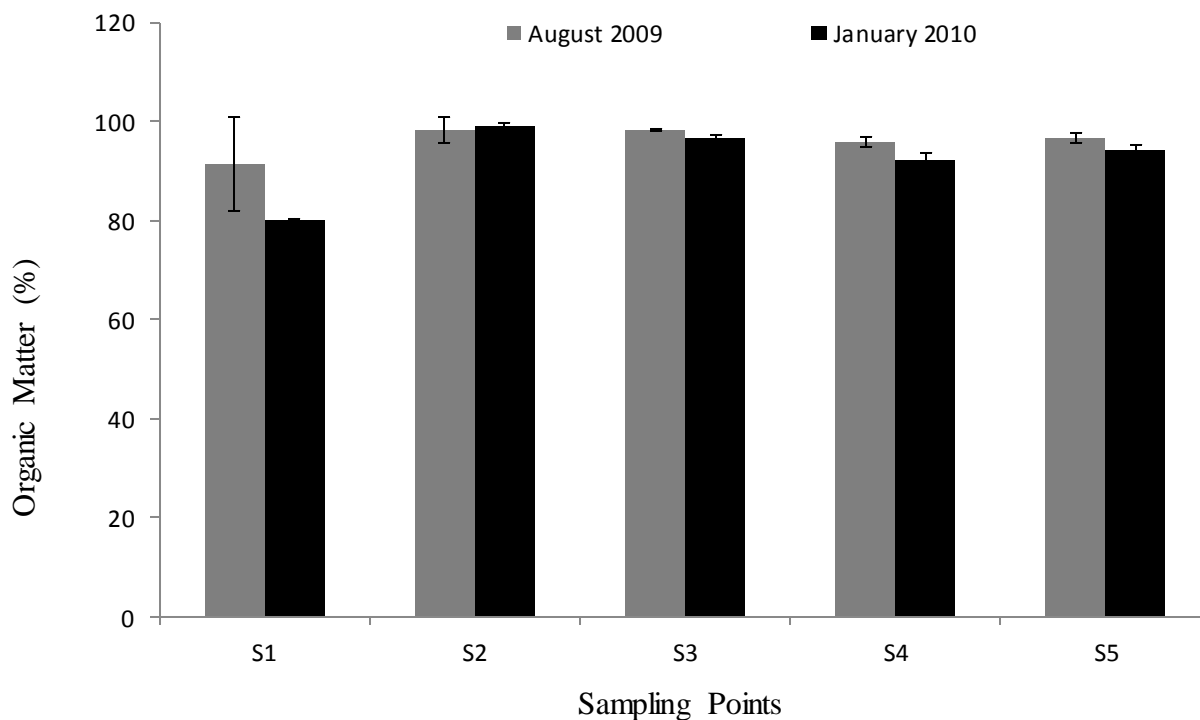

Figure 7: The mean soil water content of sampling points in August 2009 and January 2010

Soil Organic Matter

Mean range of soil organic matter content observed at a depth of 0 cm is from 84.78% to 97.95% (Figure 8), while the mean range of soil organic matter content observed at a depth of 50 cm is from 96.40% to 99.94%. This clearly shows the mean value of soil organic matter increases with depth. Figure 9 shows the mean value of soil organic matter in August 2009 and January 2010. The mean value of soil organic matter in August (95.9 ± 2.82%) was higher than in January (92.47 ± 0.16%). T test ($p = 0.267$) on soil organic matter showed no significant difference between the mean of August and January.

Figure 8: The mean (± standard deviation) organic matter with respect to sampling points and depths
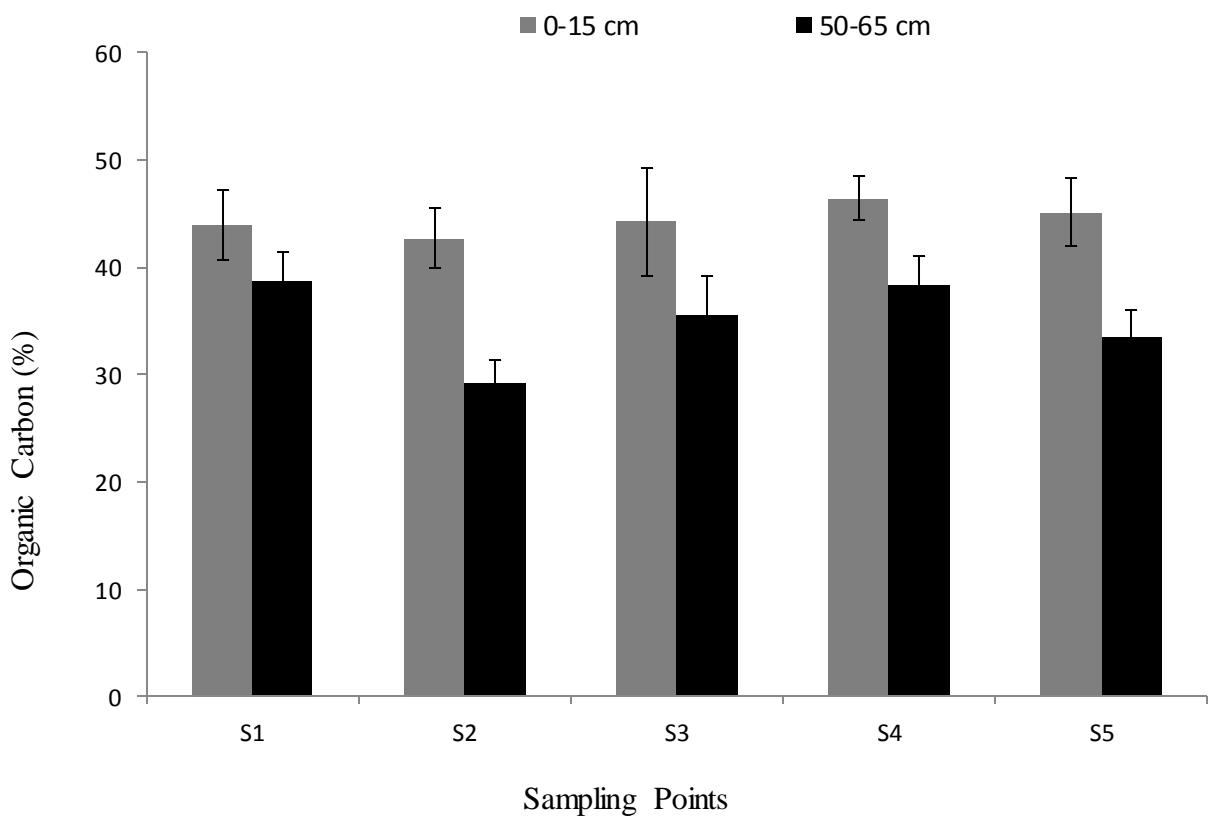

Figure 9: The mean soil organic matter of sampling points in August 2009 and January 2010

14

High water content reduces ventilation or oxygen concentration in the soil. The decrease of oxygen content in the soil will decrease the mineralization rate causing organisms to be inactive or dead. This will increase the organic matter content in the soil (Bot & Benites, 2005). Good drainage in peat soil allowed water from the heavy rainfall that occurred in August 2009 to drain into the soil more easily.
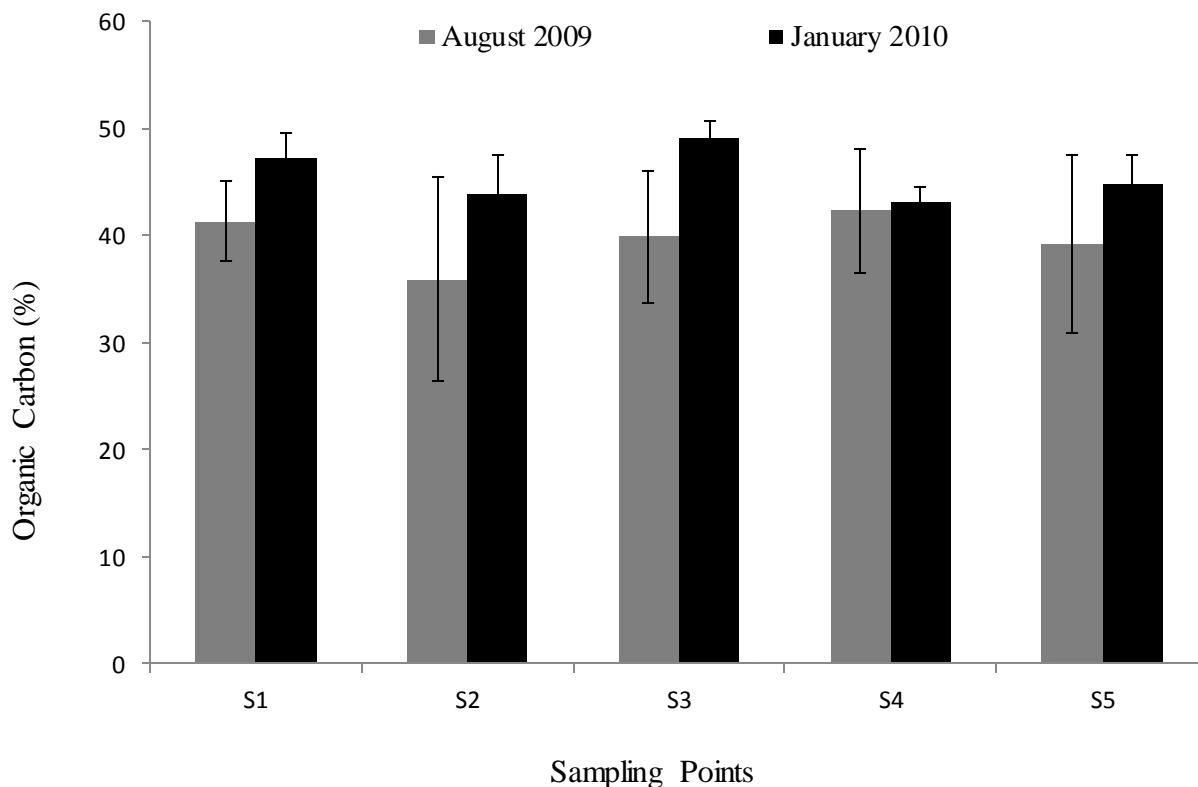
Soil Organic Carbon

Figure 10 shows the mean soil organic carbon content at different depths. At a depth of 0-15 cm, the mean range of soil organic carbon observed at all sampling points was between 42.64% and 46.43%. Mean range of soil organic carbon observed at a depth of 50-65 cm was between 29.24% and 38.79%. The soil organic carbon content in the soil increases with depth at each sampling point. Figure 11 shows soil organic carbon content in August 2009 and January 2010. The organic carbon content was higher in January. The average value of the organic carbon content in January was 45.66 ± 1.19% and in August 39.77 ± 6.66%. T test (p = 0.004) showed organic carbon content of soil in August and in January differ significantly.

Figure 10: The mean (± standard deviation) organic carbon content with respect to the sampling points and depths

Figure 11: Mean soil organic carbon content of sampling points in August 2009 and January 2010

The organic carbon content was higher on the surface and decreases with depth. This is due to the organic carbon being dissolved easily by water movement. At depths greater than 50 cm the water content is higher, therefore organic carbon dissolves more readily and were driven into groundwater resulting in reduced organic carbon content. Thus, a lot of carbon is present in the soil nearer to the surface and reduces deeper in the soil (Davidson & Ackerman, 1993). The carbon content in the soil near the surface is also attributed by the supply of new humus from decomposed plant waste (Houghton & Hackler 2000). Bot and Benites, (2005) explained that high amount of rainwater can reduce the decomposition of soil organic matter. Decomposition of organic matter will reduce the content of organic carbon in the soil.

Humic Acid

Figure 12 shows that at a depth of 0-15 cm, the mean range of humic acid content observed at all sampling points was between 42.8 mg g^{-1} soil up to 55.3 mg g^{-1} soil. In contrast, the mean range of humic acid content that was observed at a depth of 50-65 cm at all sampling points was between 41.2 mg g^{-1} soil up to 50.3 mg g^{-1} soil. Humic acid content decreased with soil depth at each sampling point except for sampling point S2. Figure 13 shows the mean humic acid content in August 2009 and January 2010 at each sampling point. The average in August and January was 48.57 ± 0.184 mg g^{-1} soil and 28.56 ± 0.085 mg g^{-1} soil, respectively. T test (p = 0.055) indicates that humic acid content in the soil was not significantly difference (p>0.05) between the mean of August and January. Humic acid content reduced substantially with depth of the soil, due to decreasing carbon content deeper into the soil. Low humic acid content at depth of more than 50 cm showed that humic acid seeps away from soil through water movement at a lower depth. Thus, there is an abundance of humic acid in the top layer whereas in the sub-soil it is scarce (Davidson & Ackerman, 1993). In addition, high humic acid content in the soil surface can also be caused by the use of fertilizers

(Houghton & Hackler, 2003). Humic acids can stimulate the microorganisms activity in the soil by supplying carbon as a food source for the microorganisms, and thus promoting their growth and activity. These microorganisms play roles in dissolving key nutrients such as phosphorus for absorbtion by humic acid and made readily available for use by plants (Zeller *et al.,* 2001). The presence of carbonate in organic soil accelerates the humification process which leads to the formation of humic acid (Puget *et al.,* 2005).
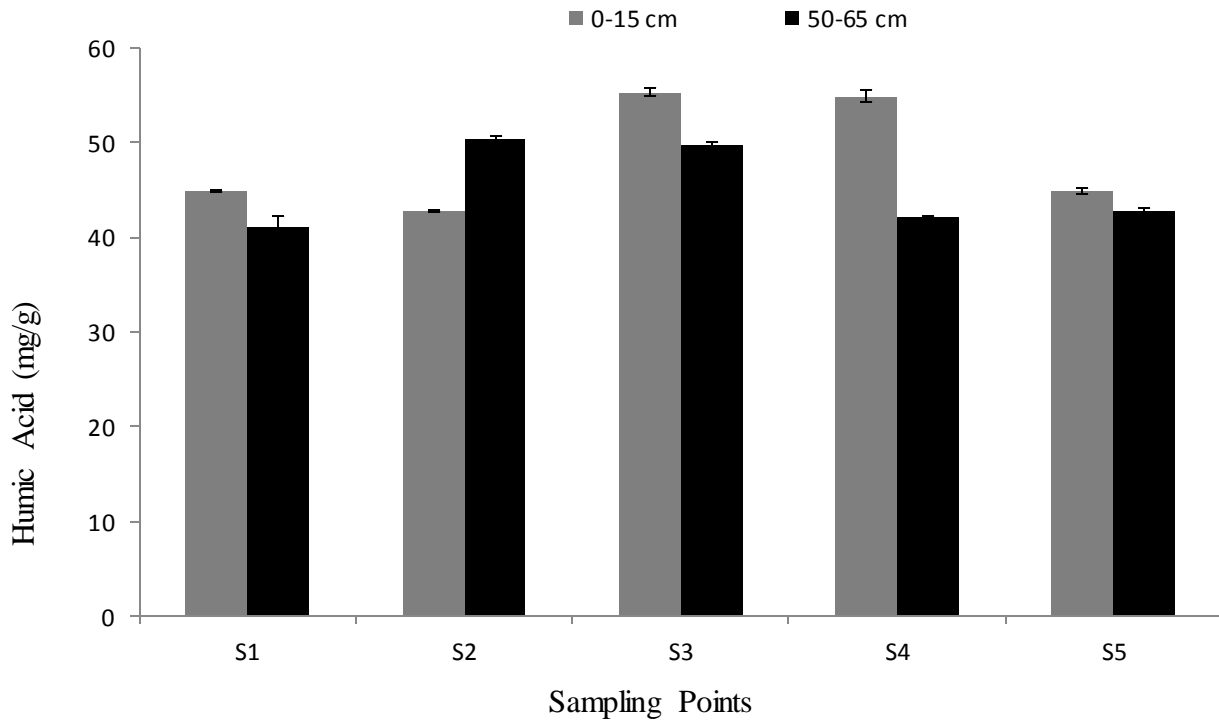

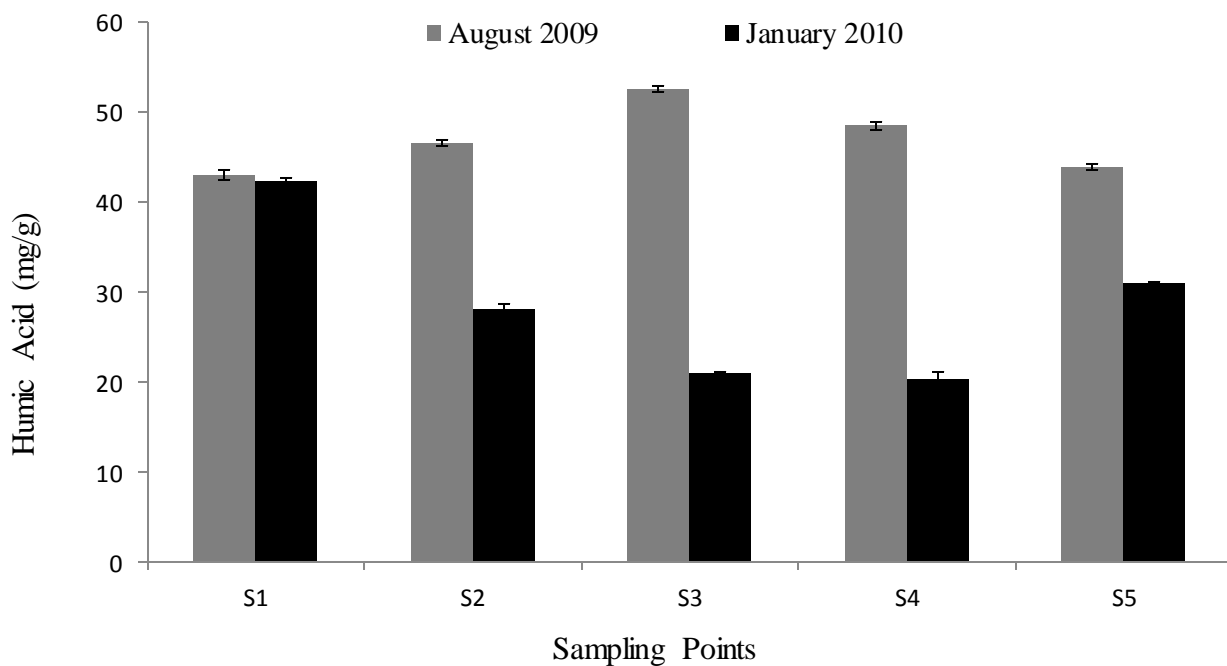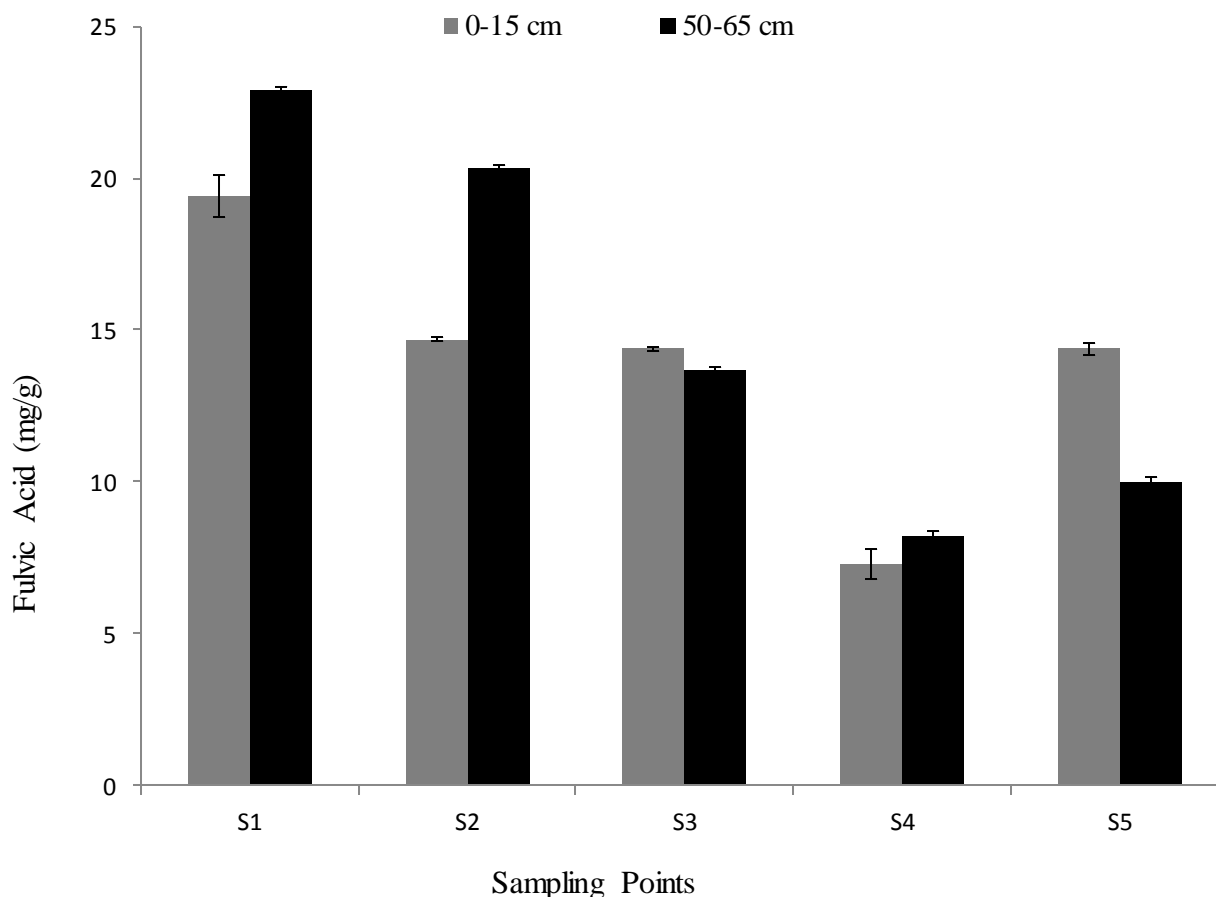Figure 12: The mean (± standard deviation) humic acid with respect to point sampling and depth
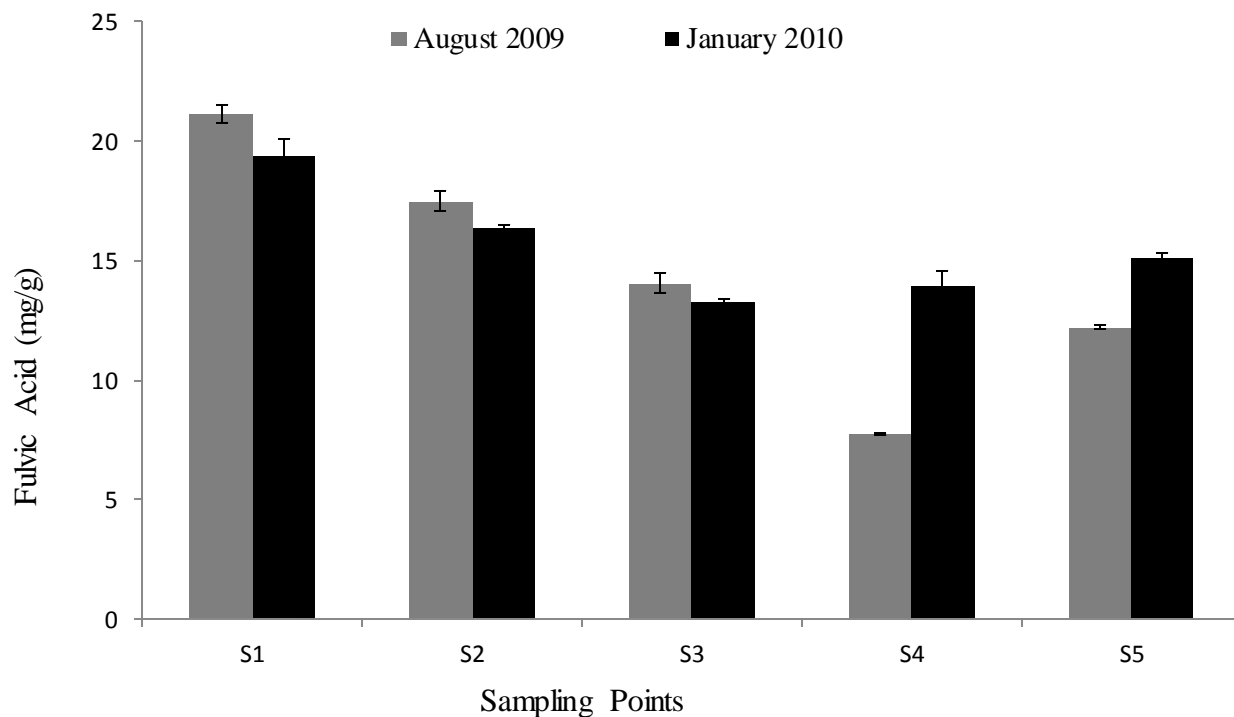

Figure 13: The mean soil humic acid of sampling points in August 2009 and January 2010

Fulvic Acid

Figure 14 shows that at a depth of 0-15 cm, the mean range of fulvic acid content observed at all sampling points was between 8.00 mg g^{-1} soil to 20.00 mg g^{-1} soil. In contrast, the mean range of fulvic acid content observed at a depth of 50-65 cm at all sampling points was between 9:00 mg g^{-1} soils to 23.00 mg g^{-1} soil. The mean value of fulvic acid content increases with depth of soil at all sampling points, except at S5 which showed a decrease. Figure 15 shows the mean value of fulvic acid content in August 2009 and January 2010. The mean value of fulvic acid content was higher in January compared to August. The average in August was 13.90 $\pm$ 0.14 mg g^{-1} soil while in January it was 15.70 $\pm$ 0.14 mg g^{-1} soil. Paired t tests (p = 0.181) showed that the soil mean fulvic acid content in August and January did not differ significantly. The fulvic acid content in the soil surface varied. This may have been caused by the use of fertilizers, particularly high amounts of nitrate fertilizer and pesticides in agricultural areas which have affected the life of microorganisms in the soil, causing disruption to the production of fulvic acid (Jacot *et al.,* 2000). Fulvic acid is soluble in water therefore it can get into the bottom part of the soil by water movement (Davidson & Ackerman, 1993), which led to an increase in the fulvic acid content at a depth of more than 50 cm.

Figure 14: The mean ($\pm$ standard deviation) fulvic acid in soil with respect to sampling points and depths

Figure 15: The mean fulvic acid of sampling points in August 2009 and January 20

Quantity of Carbon Dioxide Emissions

The mean range of CO_2 emissions was between 10.71 t CO_2 ha^{-1} yr^{-1} to 84.35 t CO_2 ha^{-1} yr^{-1} in August 2009 with an average and standard deviation of 40.92 ± 21.62 t CO_2 ha^{-1} yr^{-1} (467.10 ± 246.86 mg CO_2 m^{-2} hr^{-1}. In January 2010, the mean range of CO_2 emissions was between 12.07 t CO_2 ha^{-1} yr^{-1} to 81.31 t CO_2 ha^{-1} yr^{-1} with the average and standard deviation of 41.51 ± 13.41 t CO_2 ha^{-1} yr^{-1} (473.86 ± 153.12 mg CO_2 m^{-2} hr^{-1}). Mean CO_2 emissions from the soil between the two months showed no significant difference. The CO_2 emission in the two months of sampling was similar to the CO_2 emissions (CO_2 6.9 ± 483 mg / m^2 J) recorded in the Örke peat soil in Sweden (Berglund, *et al.*, 2008). CO_2 emissions measured in peat soil in Southern Quebec recorded by Glenn, *et al.* (1993) was 16.4-127.4 kg CO_2 ha^{-1} day^{-1} (1.4-11.2 t CO_2 ha^{-1} yr^{-1}). CO_2 emissions recorded by Melling *et al.*, (2005) on peat soil area planted with oil palm in Sarawak was 46 to 335 mg CO_2 m^{-2} hr^{-1}. Recent study by Ishikura *et al.*, (2019) shows that carbon dioxide emission from peat forest in Maludam National Park, Sarawak range from 891 ± 476 g C m^{-2} y^{-1} to 926 ± 610 g C m^{-2} y^{-1}). CO_2 emission recorded in this study (467.10 ± 246.86 mg CO_2 m^{-2} hr^{-1} in August and 473.86 ± 153.12 mg CO_2 m^{-2} hr^{-1} in January) was slightly higher than that recorded by Melling, *et al.* (2005). This situation occurred because 1) the different type of agricultural activity, where in Sarawak the soil was planted with oil palm while in Kg. Tumbuk the soil was planted with turmeric. 2) Method of determining CO_2 emissions in Kg.Tumbuk was absorption method (Kirita, 1971) where the change in CO_2 content is very sensitive to sample handling while Melling *et al.*, (2005) used the Closed-Chamber Method (Crill, 1991) to collect samples of CO_2 emissions which were then measured using Infrared Gas Analyzer (Fuji Electric ZFP-5) which is a neater method of sampling. Melling *et al.*, (2005) also recorded CO_2 emissions in forest ecosystems and sago in Sarawak which was 100 to 533 mg CO_2 m^{-2} J^{-1} and 63 to 245 mg CO_2 m^{-2} J^{-1}, respectively. This shows that the type of land use can affect CO_2 emissions in peat soil. Yew *et al.*, (2010) also reported that in the tropics the average carbon dioxide emission was 51,500 kg ha^{-1} yr^{-1} (51.5 t ha^{-1} yr^{-1}).

**Correlation between Carbon Dioxide Emissions Soil Parameters**

The correlation results in Table 1 show the relationship between CO_2 emissions and other tested soil parameters. The results show that CO_2 emission had a significant positive correlation ($p < 0.001$, $r = 0.919^{***}$) with soil organic matter (SOM), ($p < 0.01$, $r = 0.846^{**}$) with soil water content (FW) and ($p < 0.05$, $r = 0.666^*$) with temperature (T). CO_2 emission correlation with pH, bulk density, content of humic acid and fulvic acid was not significant.

Table 1: Correlation between carbon dioxide emissions (CO_2) and soil parameters

	CO_2	Fresh Water	Organic Matter	Temperature	Bulk Density	pH	HA	FA
CO_2	1							
FW	0.846**	1						
OM	0.919***	0.965***	1					
Temp	0.666*	0.317	0.477	1				
BD	-0.199	0.125	0.003	-0.277	1			
pH	0.370	0.126	0.198	0.319	-0.005	1		
Humic Acid	0.293	0.519	0.355	-0.289	-0.022	-0.276	1	
Fulvic Acid	-0.387	-0.726*	-0.615*	0.269	-0.097	-0.055	-0.622*	1

n=10; r≥0.602*, p=5%; r≥0.735**, p=1%; r≥0.847***, p=0.1%

The effect of organic matter and soil water content to CO_2 emission shown in Figure 16 was high with regression coefficients of 84.45% and 71.5%, whereas the temperature effect was not very high, even though significant, with regression coefficient of 44.3%.
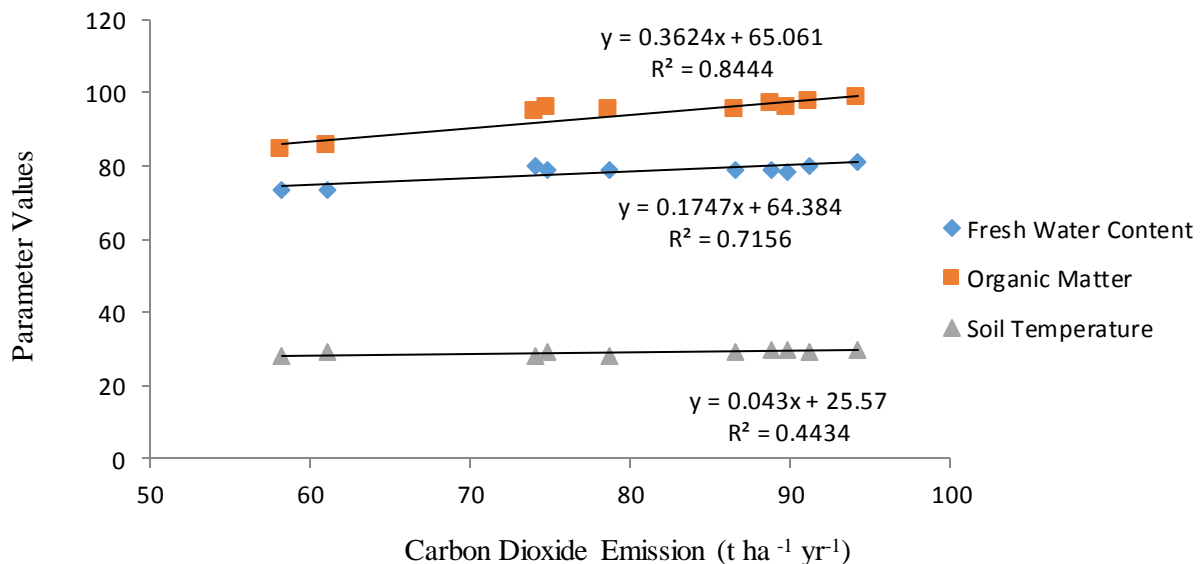
Figure 16: Regression chart showing soil parameters that affects CO_2 emission

The quantity of CO_2 emissions from soil is the total root respiration and the heterotrophic decomposition of soil organic matter (Savage & Davidson, 2001) as well as microbial respiration and oxidation of organic matter (Tan, 1994). CO_2 emission also varies with the ecosystem (Raich &

Tufekcioglu, 2000), season, the quantity and quality of organic matter (La Scala *et al.,* 2000) and environmental factors such as temperature, humidity (Mosier, 1998; Kies & Butterbach-Bahl, 2002), and pH (Tan, 1994). The correlation results in Table 1 for the study area showed a similar relationship. The high content of organic matter in the soil with an average value of 92.47% to 95.90% acted as a quality source of CO_2. CO_2 emission produced from the oxidation of organic matter and respiration activity of microbes that live on the abundant organic matter. Carbon dioxide can also be produced through the process of mineralization and decomposition of organic matter where the end products are CO_2 and water (Tan, 1994). When there is more organic matter present in the soil, more CO_2 is produced. The peat soil of the study area has a large stock of organic carbon (397.70 to 456.60 t ha^{-1}), making it a major CO_2 reservoir as well.

Silvola *et al.,* (1996) found that temperature is a significant controlling factor of CO_2 production in the soil, while Lafleur *et al.,* (2005) reported that temperature is the only factor that controls soil respiration. Temperature has a clear impact on the evolution of CO_2 emission from the soil. The temperature of the soil in the study area has a low fluctuation range of 2°C, with the temperature gap between 28-30°C. This temperature range is able to influence the increase in CO_2 emissions, despite minor as shown in the graph slope of CO_2 emission versus temperature (Figure 16) which is 0.043 only. A 1°C increase in temperature can cause loss of as much as 10% of carbon mentioned in Monika *et al.,* (2002) which was higher than the loss of carbon in the study area at 4.3%. Wiant, (1967) found that the evolution of the CO_2 increases logarithmically at temperatures between 20°C to 40°C and decreases rapidly at temperatures above 50°C. CO_2 emission increases at 20-40°C interval can be attributed to increased activity of roots and decaying organic matter (Bunt & Rovira, 1954). The average soil temperature at 29°C in the study area was within the interval where the activity of roots and decaying organic matter increases, which can contribute to increased CO_2 emissions from the soil.

Soil moisture affects the soil respiration and CO_2 emission. Normally, an increase in soil moisture will increase CO_2 emissions to the optimum level. This is because in dry soil microbial activity occurs slowly and increases when the soil gets wet. The water content of soil in the study area based on the weight of the soil is high with mean values of 77.07% in the top soil and 81.78% in the sub soil. However, based on volume, water content in the top soil is 15.41% (v / v) and sub-soil is 21.26% (v / v) which showed pore space in the soil was mostly filled by air. Therefore, microbial life favours a state that has a good balance between air and water in the soil. Correlation analysis shown for CO_2 emission with water content in Table 1 was significantly positive ($p < 0.01$), which shows increased CO_2 emission with increasing soil moisture content.

The quantity of CO_2 emission is very little in acidic soils, and increases with higher pH. Low pH conditions negatively impact soil microbial activity by lowering respiration rate and further reduce CO_2 emission (Pol van Dasselaar *et al.,* 1998). The pH value in the study area was low in August at 3.14 and slightly higher in January at 4.43. CO_2 emission data showed slightly higher values in January compared to August. This corresponds to the slightly higher pH value in January.

Changes in the physical characteristics of the soil caused by ploughing activities can increase the quantity of CO_2 emission when compared to non-ploughed soil. This is because ploughing will break down soil aggregates, helping the soil to mix with organic particles, increases water infiltration and soil's ability to retain water, ultimately causing an increase in CO_2 production (Monika *et al.,* 2002). Turmeric cultivation activities on the study site need to go through a ploughing process to

provide bedding for seeding. CO_2 emission recorded in the turmeric cultivation area is slightly higher than the carbon emission in oil palm estates as reported by Melling *et al.,* (2005).

The supply of organic fertilizers to agricultural soil to supply nutrients to plants may also increase the quantity of CO_2 emission. Organic carbon from dissolved organic fertilizer in the soil is a source of carbon that can promote the growth of microorganisms which in turn increases CO_2 emissions from the soil (Monika *et al.*, 2002).

CARBON STOCK

Carbon Stocks in August

The study site has a length and width of 100 m each and the depth of soil at the study site is 0.5 m. The average percentage of carbon content and an average bulk density of the soil is 39.77% and 0.20 $g\ cm^{-3}$, respectively.

The calculation of carbon stock is as follows: -

Soil volume $= 100\ m\ x\ 100\ m\ x\ 0.5\ m = 5000\ m^3$

$$= 5000\ 000\ 000\ cm^3$$

Soil mass $= 0.20\ g\ cm^{-3}\ x\ 5000\ 000\ 000\ cm^3 = 1000\ 000\ 000\ g$

$$= 1000\ t\ ha^{-1}\ soil$$

Soil carbon stock $= 39.77\%\ x\ 1000\ t$

$$= 397.70\ t\ ha^{-1}\ carbon$$

So, the soil mass at the study site with measurements 100 m long, 100 m wide and 0.5 m deep is 1000 $t\ ha^{-1}$ while the carbon stock for this site is 397.70 $t\ ha^{-1}$.

Carbon Stocks in January

The study site has a length and width of 100 m respectively. Mean percentage of carbon content and means bulk density of soil at a depth of 0.5 m was 45.66% and 0.20 $g\ cm^{-3}$, respectively.

The calculation of carbon stock is as follows: -

Soil volume $= 100\ m\ X\ 100\ m\ X\ 0.5\ m = 5000\ m^3$

$$= 5000\ 000\ 000\ cm^3$$

Soil mass $= 0.20\ g\ cm^{-3}\ X\ 5000\ 000\ 000\ cm^3 = 1000\ 000\ 000\ g$

$$= 1000\ t\ ha^{-1}\ soil$$

Soil carbon stock $= 45.66\%\ X\ 1000\ t$

$$= 456.60\ t\ ha^{-1}\ carbon$$

The soil mass at the study site measuring 100 m long, 100 m wide and 0.5 m deep with bulk density of 0.20 $g\ cm^{-3}$ is 1000 $t\ ha^{-1}$ while the carbon stock at this size is 456.60 $t\ ha^{-1}$. The content of carbon stock was higher in January 2010 than in August 2009. The difference in carbon stock at the two

samplings period was due to the differences in soil organic carbon content which were determined at different times. However, the difference was not significant. Previous studies in peat soil not far from this study area by Sahibin, *et al.* (2011) showed that carbon stock in the same size of land is slightly higher with 872.72 t ha^{-1} measured at a depth of 0.8 m and a higher bulk density of 0.26 g cm^{-3}. Carbon stock in peat soil is much higher than carbon stock in the mountain area of Fraser's Hill which recorded a carbon stock range of 217.90 t ha^{-1} to 223.24 t ha^{-1} (Mohamed *et al.,* 2016).

CONCLUSION

Peat soil used for the cultivation of turmeric in Kampung Tumbuk Darat, Kuala Langat Selatan had CO_2 emission similar to other peat soil areas in Malaysia. The average quantity of CO_2 emissions obtained in August was 467.10 ± 246.86 mg CO_2 m^{-2} hr^{-1} (40.92 ± 21.62 t CO_2 ha^{-1} yr^{-1}) while January had an average emission of 473.86 ± 153.12 mg CO_2 m^{-2} hr^{-1} (41.51 ± 13.41 t CO_2 ha^{-1} yr^{-1}). CO_2 emission recorded by Melling, *et al.* (2005) in the peat soil area in Sarawak oil palm cultivation is 46 to 335 mg CO_2 m^{-2} hr^{-1}. This shows that the CO_2 absorption principle in Kirita method can be used to determine CO_2 emission from the soil.

One hectare study area with a depth of 0.5 m has 397.70 t ha^{-1} carbon stock in August, 2009, while in January, 2010 the total carbon stock is 456.60 t ha^{-1}. The volume of soil to an area of one hectare to a depth of 0.5 m that is calculated is 5000 m^3, with average bulk density of 0.20 g cm^{-3} and soil mass 1000 t ha^{-1}.

The average surface temperature of peat soil in the study site is 29°C. Average pH in peat soil was acidic with a pH value in August and January at pH 3.14 and pH 4.43, respectively. Soil fresh water content when sampling in August and January were respectively 80.22% and 56.15% with heavy rainfall in the sampling in August. Organic content of soil in both months is very high, which is at 95.97% and 92.47%. Organic carbon content, humic acid and fulvic acid in the soil in January were higher compared with August.

It was found that CO_2 emissions in soil in the study area was influenced by organic matter content, soil water content and soil temperature.

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