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Forest Logging and It Impact on Soil Carbon Dioxide Effluxin the tropical Forest, Peninsular Malaysia

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Abstract:*Forest harvesting is expected to have an impact on soil CO_2 efflux as it influence soil properties and changesinmicroclimatic conditions which can have implications on the regional carbon balance. Soil CO_2 efflux was measured using a continuous open flow chambers technique connected to a multi-gas-handling unit and infrared CO_2/H_2O gas analyser. Soil temperature, soil moisture, water potential, Total Organic Carbon (TOC), Soil Organic Carbon (SOC), Soil Organic Carbon stock (SOCstock), Bulk density and pH were examinedto ascertain their contribution onsoil CO_2 efflux and effect ofenvironmental factors in a canopy gap created through the logging of groups of trees in the Sungai Menyala forest, Peninsular Malaysia. The aim was to determine soil CO_2 efflux and the change in soil properties resulting from deforestation. Multiple regression shows a strong relationship (r^2=0.949; $p<0.01$) between the soil CO_2 efflux and soil properties resultedfrom deforestation. SoilCO_2 efflux ranged from 143.14 to 364.17, 103.26 to 404.81, 111.17 to 466.78, 234.72 to 445.03 and 277.25 to 475.3 mg $m^{-2}h^{-1}$ from February to June 2013, respectively, and varies withtime present in the higher soil temperature and the amount of TOC, SOC, SOCstock. We found that soil CO_2 efflux in logged-over land was much higher compared to that in the recovering and primary forest. Soil temperature was found to have a strong effect on the increase in soil CO_2 efflux;similarly, the change in soil properties was found to have a positive effect. The resultssuggested that forest harvest has a strong influence on soil CO_2 efflux through changes in the soil temperature and soil properties.*

Keywords: *Atmospheric carbon pool, Logged-over;Microbial; Organic carbon; Soil CO_2 efflux.*

I. Introduction

Soil in the terrestrial ecosystem has been reported to contribute about 68–100Pg carbon year^{-1} and 60–80Pg carbon year^{-1} into the atmosphere, which is 30–60% greater than the terrestrial net primary productivity [1,2]. This magnitude of soil CO_2 efflux is large enough to exacerbatetheincrease in the atmospheric CO_2 with implications on climate change [3]. The driving force behind the spatial and temporal variation of soil CO_2 efflux has been attributed to temperature and moisture [4], while other critical factors that are associated are water content and soil organic materials[5,6].

Forest harvesting, land conversion and disturbance have considerable implications on soil CO_2 efflux, and have been reported to either increase or decrease CO_2 efflux from forest soils compared to undisturbed forest [6,7]. The overall effect of deforestation will displace the aboveground biomass as the forest ecosystem serves as a carbon sink, and carbon assimilation via photosynthesis resultsin the efflux of CO_2 into the atmospheric carbon pool [8]. Forest harvesting causes drastic and unexpected changes in the microbial activity, litter fall input, root density, production and insolation, which results in predictable changes in the CO_2 efflux from forest soils. [9] reported that forest harvesting has a negative impact on the forest soil CO_2 and that it has yielded various degrees of inconsistent results. Large increases and large decreases in soil CO_2 efflux have been recorded in respect of the general ecological system [5, 10].

The major challenge with deforestation concerns the impact of soil CO_2 emission rates as it reduces the efficiency of root respiration compared to that of an undisturbed forest ecosystem, and results in the death of the root systems of the harvested trees, which reduces or eliminates the contribution of root respiration, as the root system accounts for about 50–70% of soil respiration [11]. Forest harvesting disturbs the physiological activity of tree roots and microbial conditions, which could likely have a large impact on the soil CO_2 efflux [12,13]. However, the CO_2 efflux from the soil due to forest harvesting is quite high as a result of the decay of fine roots and increased temperature for microbial activity.In addition, this scenario could vary over time. In the tropical forest of Malaysia, studies have not being documented concerning the impact of deforestation on the soil CO_2 efflux, despite several years of deforestation. Although soil CO_2 fluxes are critical to fully understand the different forest management systems, there are few studies in Malaysia concerning the response of soil CO_2efflux to either partial stand harvesting or fully logged areas. This study determines the soil CO_2 efflux and changes in the soil properties resulting from the effect of deforestation.

II. Materials And Methods

2.1 Site description

The study site was located in a 2 ha logged-over*dipterocarpus* forest of Sungai Menyala forest (27°50′95″N 43°64′99″E),Port Dickson, Peninsular Malaysia. The forest experiences equatorial climatic condition with a monthly rainfall of 200mm between October and January, with theoccurrence of light showers between February and September[14]. The area has a mean annual temperature range of 23.7–32°C and relative humidity of 59–96%[15], and the soil is classified as the Serdang-Kedah series developed over mixed sedimentary rocks with a combination of local alluvium colluvium resulting from metamorphic rock [16,17]. In the FAO/UNESCO Soil Map of the World – Revised Legend ,the Serdang series is classified as Haplic Nitisols [18].

2.2 Experimental design

The study examines soil CO_2 efflux in responses to logging activities, as 50 x 50 m plot was demarcated in a canopy gap created as result of logging of group's trees. This was conducted in a split plot designed as the logged area and as the main plot effect while two replicates of another logged area and a non-logged forest area. The logging was conducted in 2006 providing seven years after harvesting. The replicate stand designates a portion of a logged-block relatively homogeneous in species composition, forest structure, and the stand is of the same soil and topography. Also the replicate logged area and stand forest was sampled in spatially non-contiguous where possible with locations chosen to maximize spatial interspersion among harvest date. There were thirty measurement points at each plot location, at a space distance of 5 m, given a total of 150 sampling points in the study (1 logged-over area as main plot, 2 replicates logged-over plots and 2 non-logged-over plots areas).

2.3 Measurement of soil CO_2 efflux and related environmental parameters

Soil CO_2 efflux was measured on a daily basis, from 0800 – 1700hour, from February to June, 2013 representing the tropics season. Two constructed continuous open flow chambers of 64 cm in height and 50 cm width, having a flow fan for the mixture of CO_2. The chambers were connected to a multi gas-handler (WA 161 model), which provides a channel to regulate the flow of CO_2 from various chambers to a flow meter connected with a CO_2/H_2O gas analyser (Li-Cor 6262)[19]. Soil CO_2 efflux was recorded every 5sec over a period of 5min in each chamber, from which an average was calculated to estimate the CO_2 concentration over 5min for each chamber. A standard calibration (zero setting) of CO_2 and H_2O was carried out using silica gel and soda lime. A 3 cm thick closed foam gasket was placed between the chamber base and the soil collar to prevent leakage while soil collars were randomly inserted 3 cm into the soil for 24 hours before commencement of measurement for soil pressure to stabilize in order to create an equilibrium stage and kept in place throughout the entire period of the study. The daily data were collected at the whole study areas with a similar weather pattern.

Soil temperature, soil moisture and water potential was measured using probes (Watchdog data logger model 125 spectrum technology, Delmorst model KS-D1 and Trime-Fm TDR), respectively at 5cm below the soil surface concurrent with soil CO_2 measurement. Soil samples were collected from three different locations at randomusing the soil core with a metal core sampler of 10 cm in diameter and 10 cm in height at a depth of 0-100 cm. The volume of the core sampler was determined using the equation one (1). The sample was preserved with the metal cylinder core in an airtight plastic bag and taken to the laboratory for determination of pH using a glass electrode in a saturated soil water paste, Total Organic Carbon (TOC), Soil Organic Carbon (SOC) and soil moisture content using the Walkley-Black standard method with a correction factor of 1.33 in related to Sollins et al. (1999), as it is appropriate for moisture analyses because of its simplicity. The carbon and nitrogen ratioswere determined from the replicate forest stand based on equations two to nine (2-9).

$$V = \pi r^2 h \ldots \ldots [1]$$

Where; V= volume (cm^3), r = the radius of the core sampler (cm) and h is the height of the core sampler (cm). The soil samples were weight, air dry and oven dry at 105^oC for 48 hours.
The earth bulk density, which indirectly provides a measure of the soil porosity (pore spaces), was determined using the standard method of soil analysis (Nhantumbo and Bennie 2001).

$$\text{Bulkdensity}(\text{Mgm}^{-3}) = {}^{g}/_{V} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

Where; g= oven dry mass of the sieve soil (g), V= sample volume (cm^{-3}).
The soil moisture content was determined in accordance with the standard method based on the following equation:

$$\text{Moisturecontentinwt\%} \ ({}^{W}/_{W})\text{isobtainedby}:$$

$$\text{Moist(wt\%)} = \left[\frac{(A - B)}{(B - \text{taretin})}\right] x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [3]$$

The corresponding moisture correction factor (mcf) for analytical results is:
$\text{Moisturecorrectionfactor} = (100 + \%\text{moist})/100.$
Where, A=air dry soil, B=oven dry soil.
The Total Organic Carbon (TOC) was determined by the Walkley-Black method using a correction factor of 1.33[20], as it is appropriate for moisture analyses because of its simplicity;

$$\text{Toc}(\%M) = Mx\left[{}^{(V1 - V2)}/_{S}\right] x\ 0.39\ x\text{mcf} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [4]$$

Where:
M = molarities of ferrous sulphate solution (from blank titration)
V1 ml ferrous sulphate solution required for blank
V2 ml ferrous sulphate solution required for S = weight of air dry sample in grams
mcf = 3 (equivalent weight of carbon) corrected factor.

Soil Organic Carbon (SOC) was determined using the following equation:

$$M = {}^{10}/_{\text{Vblank}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

$$\%\text{oxidizableorganiccarbon}({}^{W}/_{W}) = {}^{[\text{Vblank} - \text{Vsample}]}/_{\text{Wt}}\ x\ 0.3\ x\text{mass} \ldots\ldots [6]$$

$$\%\text{totalorganiccarbon}({}^{W}/_{W}) = 1.334\ x\ \%\ \text{oxidazableorganiccarbon} \ldots\ldots\ldots\ldots [7]$$

$$\%\text{organicmatter}({}^{W}/_{W}) = 1.724\ x\ \%\text{totalorganiccarbon} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [8]$$

Where:
M = molarities of ferrous ammonium sulphate solution (app $0.5cm^{-3}$)
V blank = volume of ferrous ammonium sulphate solution required to titrate the blank (cm^{-3})
= Volume of ferrous ammonium sulphate solution required to titrate the sample (cm^{-3})
wt = weight of air dry soil (g)
$0.3 = 3 \times 10^{-3} \times 100$ where 3 is the equivalent weight of C
The Soil Organic Carbon Stock was ascertained to verify the amount of the stock of carbon held in a given area of the soil, taking cognisance of the compaction and depth of the soil while the earth bulk density had to be determined. The soil depth recommended for the stock of carbon assessment is the top 100cm [21]. The Soil Organic Carbon Stock held in a given area of soil can then be expressed as:

$$\text{SOC}_{\text{stock}} = \left[\frac{\text{SOCcontentofsoil} \times \text{BD} \times \text{area} \times \text{depth}}{10}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [9]$$

Where:
SOC= Soil Organic Carbon
BD= Bulk Density
Depth= Depth of the soil.
Soil pH and Electric conductivity was determined.

III. Statistical Analysis

Statistical tests for the effect of loggingand its interaction with soil moisture, temperatureand changes soil properties on soil CO_2 efflux were performed using a parametric one-way ANOVA, followed by a post hoc Dunn's test and Turkey multiple comparison test. The analysis of variance (ANOVA) was used to test the difference of standard deviation and mean soil CO_2 efflux. No transformation of soil CO_2 data, soil temperature and moisture data was conducted as they satisfied the normality and homoscedasticity assumptions of ANOVA. In addition, descriptive statistics were established to calculate and explain the normality of data distribution and to quantify the relationship between the soil CO_2 and the environmental factors. Multiple linear regression analysis was employed to ascertain the confounding significant effect of logging, environmental factors and soil properties on soil CO_2 efflux, with the best-fit model chosen using Akaike's Information Criterion (AIC). Likewise, Pearson correlation was calculated to show the correlation of the CO_2 efflux variation with the environmental factors.

IV. Results And Discussion

Soil CO_2 efflux was recorded to rangefrom 143.14 to 364.17, 103.26 to 404.81, 111.17 to 466.78, 234.72 to 445.03 and 277.25 to 475.3 mg $m^{-2}h^{-1}$ in the February, March, April, May and June, respectively, with an average efflux rate of 103.26–475.37 mg $m^{-2}h^{-1}$ (Table 1). Soil CO_2 efflux increase from February and reached a maximum in June (Fig. 1) similar to previous reports [22,23,24] with the minimum at 0800hrs and attending the peak between 1300hrs and 1400hrs. The efflux trend scenario coincided with the end of the monsoon regime by February and the resumption of the post monsoon in March with its peak in June. The reason behind the maximum soil CO_2 efflux in June may be attributed to the relatively high soil temperature [23]. A positive correlation ($p<0.001$)with the corresponding environmental factors of soil temperature, soil moisture and water potent occurred at 24.54–25.66^oC, 21.43–26.25% (Fig. 2) and 94.1–96.8%, respectively. The multiple linear regression model provided the best fit for describing the relationship between soil CO_2 efflux and soil temperature, soil moisture and water potential $r^2=0.816$ to 0.948 $p<0.001$ (Table 2). Furthermore, the beta coefficient from the multiple regression indicated that the soil temperature, soil moisture and water potential were responsible for the soil CO_2 efflux with a beta coefficient of 0.447, 0.204 and 0.561, respectively, in February (Table 3). Furthermore, in March, the soil temperature was a leading factor for CO_2 efflux with the soil moisture at a beta coefficient of 0.904 and water potential at constant or low level of occurrence at a beta coefficient of -1.089 and -0.116, respectively (Table 4). The soil temperature and water potential significantly influenced the soil CO_2 efflux in April with a beta coefficient of 0.546 and0 .985, respectively, with low impact of soil moisture at -0.381 (Table 5). Similarly, in May, the soil temperature and water potential were very responsible for the soil CO_2 efflux with a beta coefficient of 0.077 and 0.492,respectively,which was greater than the soil moisture at -0.513 (Table 6). A similar trend was also recorded in the month of June, the peak of the post monsoon, in which it was observed that the soil temperature and water potential were the major factors for soil CO_2 efflux with a beta coefficient at 0.608 and 0.018,respectively,while the soil moisture had less impact at -0.497 (Table 7). The overall role of the environmental factors on soil CO_2 efflux was found to be strong and significantly positively related.

Table 1: Descriptive statistics of soil CO_2 efflux (mg $m^{-2}h^{-1}$)

Table 2: The best single and multiple-regression models were generated using enter independent variable selection

Table 3: Logged-over area estimates of the coefficient of the model of environmental parameters in $^oC$and % for soiltemperature, soil moisture and water potential in February.

Table 4: Logged-over area estimates of the coefficient of the model of environmental parameters in $^oC$and % forsoil temperature, soil moisture and water potential in March.

Table 5: Logged-over area estimates of the coefficient of the model of environmental parameters in $^oC$and % forsoil temperature, soil moisture and water potential in April.

Table 6: Logged-over area estimates of the coefficient of the model of environmental parameters in $^oC$and % forsoil temperature, soil moisture and water potential in May.

Table 7: Logged-over area estimates of the coefficient of the model of environmental parameters in $^oC$and % for soil temperature, soil moisture and water potential in June.

Fig. 1. Soil CO_2 efflux trend across five months

Fig. 2. Average Soil temperature and moisture across five months

The physiochemical parameters recorded from the soil sample analysis showed considerable percentages of Total Organic Carbon (TOC), Soil Organic Carbon (SOC), soil moisture content, moisture correction factor and Soil Organic Carbon stock (SOCstock),as 2.12%, 1.4%, 15.47%, 1.15% and 23.32 $Mgha^{-1}$, respectively, while the pH was 5.75 – slightly acidic soil, (Table 8). The bulk density was recorded to increase from thedepthof 0 to 100cm (Fig 3), giving good porosity for water movement, electric conductivity, and cation exchangecapacityto hold onto soil nutrients suitable for microbialactivity.

Using statistical analysis to test for the relationship between the soil CO_2 efflux and environmental factors, one way ANOVA analysis revealed good significant differences in the soil CO_2 efflux across the months of measurement with a significant level at $p<0.001$. The post Hoc Test (Tukey/Scheff/Bonferroni) indicated a significant difference at $p<0.001$ level. The normal Q-Q plot of distribution showed that all the observed values for the various months fall along a straight line, and the box plot showed no outlier data, giving a good distribution of data with skewness (Fig. 4). The average soil CO_2 efflux was observed to range from 103.26–475.37 mg $m^{-2}h^{-1}$ similar to the open field under a semi-arid climate in China [25], and relatively higher than the onion field in Japan, 11-307 mg $m^{-2}h^{-1}$ (Hul et al. 2003). Comparing the soil CO_2 efflux in the logged-over area and the standing forest showed that the logged-over area was observed to have higher soil respiration comparedto the deciduous forest of Japan [27], the Pasoh forest of lowland Peninsular Malaysia [28], the 39-year old larch stand in Korea, [29] and the forest of Hokkaido, Japan [30]. This result indicated that the forest logging area has a higher soil CO_2 efflux, which suggests that logging has a significant long-term effect on CO_2 emissions. In order to relate the effect of CO_2 emissions to environmental factors – soil temperature, soil moisture, water potential, TOC, SOC, SOCstock, bulk density and pH – the multiple linear regression model was employed. The classical assumption for linear regression comprises the check and collinearity diagnostic, which showed that none of the conditional index models for the logged area data was above the threshold limit of 30.0. In addition, none of the tolerance values were less than 0.10 indicating no multicollinearity problem among the variables of the models. With this condition met, it is reasonable to conclude that the estimated multiple linear regression model can be used to explain the impact of environmental factors on soil CO_2 efflux. Given thatthe increase in soil CO_2 was strongly associated with an increase in soil temperature over time, the availability of soil moisture, water potential, considerable amount of TOC, SOC, SOC stock [31] and soil porosity (bulk density) also enhance the pore spaces for water movement for microbial activity in slightly acidic soil. This entire process occurred due to the change in the microclimate and soil properties of the plot area resulting from deforestation, whichcaused the death and decay of the root systems and thereby further reducing their efficiency. The deforestation also caused a change in soil temperature, soil properties and an increase in microbial activities to displace the considerable amount of soil CO_2 efflux.

Table 8: Analysis of soil samples

Fig. 3. Bulk Density

Fig. 4. Box and whisker plot of environmental parameters**.**

V. Conclusion

The study revealed that the soil CO_2 efflux and soil temperature are parallel to the associated changes in the soil properties. The results suggested that the high carbon input fromthe forest biomass and the increaseinTotal Organic Carbon (TOC), Soil Organic Carbon (SOC), Soil Organic Carbon stock (SOCstock) and bulk densityare influenced by changes in the microclimate conditions, whichincrease the soil nutrients and microorganism activity to emit soil CO_2,as was also reported by [32] and [33]. Deforestation increased the plant decay, as well as changes in the microclimate, soil properties and favourable soil pH, whichenhanced the microbial activity and displayed a high percentage of soil CO_2 directly into the atmosphere. Furthermore, the monthly variation in soil CO_2 is highly attributed to the presence of relatively high soil temperature, moderate soil moisture and water potential, which are very conducive for microbial activity [34]; [35]. The observed soil CO_2 efflux resulted from the logged-over area being higher compared tothevarious forest stands, therefore, we concluded that the logging of the forest might have considerable influence on the soil CO_2 efflux in terms of emitting a higher amount of CO_2 into the atmospheric carbon pool in respect of the future global warming scenario.

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Table 1. Descriptive statistics of soil CO_2 efflux microgram /mole/hour (mg $m^{-2}h^{-1}$)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
February	72	275.5249	61.50806	7.24879	261.0712	289.9786	143.14	364.17
March	72	272.5367	88.86396	10.47272	251.6547	293.4188	103.26	404.81
April	72	314.8683	119.76305	14.11421	286.7254	343.0113	111.17	466.78
May	72	358.8160	70.95301	8.36189	342.1428	375.4891	234.72	445.03
June	72	392.1426	58.77435	6.92662	378.3313	405.9539	277.25	475.36
Total	360	322.7777	94.96072	5.00487	312.9352	332.6203	103.26	475.36

Table 2: Best single and multiple –regression models were generatedusing enter independent variable selection

Model	R Square	Adj-R2	Std error of estimation	F	Sig
February	.830	.675	35.08583	50.067	0.001
March	.888	.779	41.78736	84.362	0.001
April	.816	.651	70.77707	45.097	0.001
May	.949	.896	22.86610	205.207	0.001
June	.891	.784	27.30075	87.022	0.001

Table 3:Logged-over area estimates of the coefficient of the model of environmental parameters in ^{0}C and % for soiltemperature, soil moisture and water potential in February

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-13627.200	2186.751		-6.232	.000		
	FEBtmp	185.898	39.631	.447	4.691	.000	.505	1.979
	FEBmt	149.756	59.588	.204	2.513	.014	.694	1.441
	FEBwp	51.569	7.514	.561	6.863	.000	.687	1.457

a. Dependent Variable: FEBCO2, FEBtmp= February soil temperature , FEBmt= February soil moisture, FEBwp=February water potential

Table 4: Logged-over area estimates of the coefficient of the model of environmental parameters in^{0}C and % forsoil temperature, soil moisture and water potential in March

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2652.121	3102.810		.855	396		
	MARtmp	544.777	46.227	.904	11.785	.000	.530	1.887
	MARmt	-435.677	30.385	-1.089	-14.339	.000	.539	1.854
	MARwp	-61.260	37.803	-.116	-1.621	.110	.611	1.636

a. Dependent Variable: MARCO2, MARtmp=March soil temperature, MARmt=march soil moisture, MARwp=March water potential

Table 5: Logged-over area estimates of the coefficient of the model of environmental parameters in ^{0}C and % forsoil temperature, soil moisture and water potential in April.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-159697.710	50947.962		-3.135	.003		
	APLtmp	170.193	48.721	.546	3.493	.001	.201	4.974
	APLmt	-210.401	122.185	-.381	-1.722	.090	.101	9.940
	APLwp	1659.239	490.792	.895	3.381	.001	.070	14.243

a. Dependent Variable: APLCO2, APLtmp=April soil temperature, APLmt=April soil moisture, APLwp=April water potential

Table 6: Logged-over area estimates of the coefficient of the model of environmentalparameters in ^{0}C and % forsoil temperature, soil moisture and water potential in May

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-50245.705	7821.863		-6.424	.000		
	MAYtmp	8.392	5.031	.077	1.668	.100	.678	1.474
	MAYmt	-163.808	20.183	-.513	-8.116	.000	.366	2.732
	MAYwp	562.946	77.108	.492	7.301	.000	.322	3.107

a. Dependent Variable: MAYCO2, MAYtmp=May soil temperature, MAYmt=May soil moisture, MAYwp= May water potential

Table 7: Logged-over area estimates of the coefficient of the model of environmental parameters in ^{0}C and % for soil temperature, soil moisture and water potential in June.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	96.487	1444.078		.067	.947		
	JUNtmp	91.737	8.705	.608	10.538	.000	.913	1.095
	JUNmt	-83.869	9.742	-.497	-8.609	.000	.913	1.095
	JUNwp	4.608	14.136	.018	.326	.745	.999	1.001

a. Dependent Variable: JUNCO2, JUNtmp=June soil temperature, JUNmt=June soil moisture, JUNwp=June water potential

Table 8: Analysis of soil samples

ECOSYSTEM	SOC %	TOC	pH	Soil Moisture Content %	Moisture Correction factor	SOCstockMg/ha
Logged Area	2.12	1.4	5.75	15.47	1.15	23.32

TOC=Total Organic Carbon, SOC=Soil Organic Carbon, SOCstock=Soil Organic Carbon stock

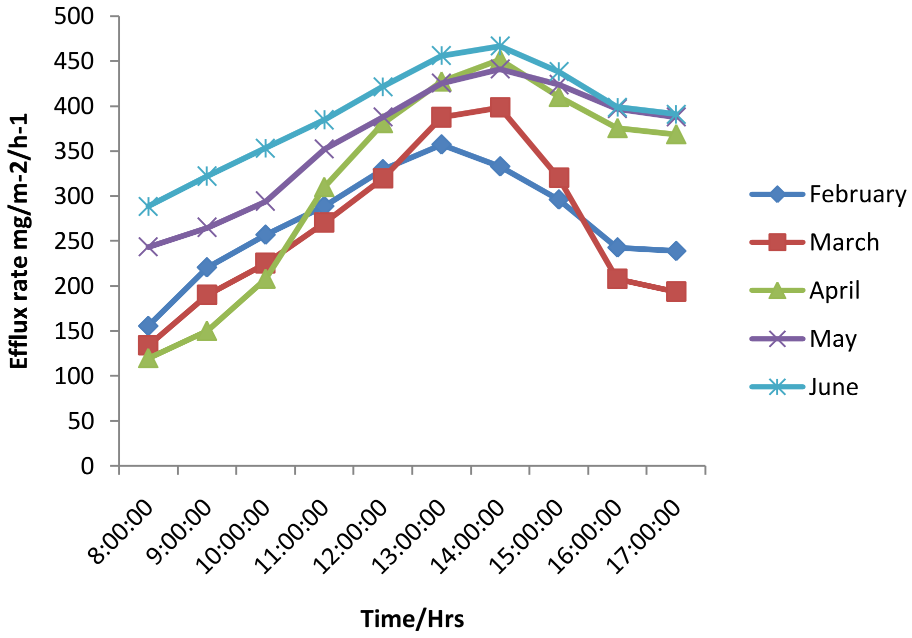

Fig. 1. Monthly Soil CO_2 efflux trend

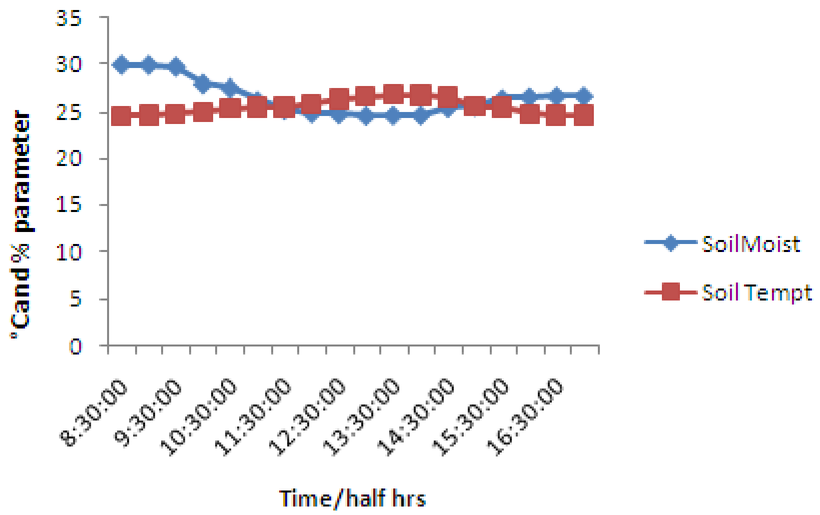

Fig. 2. Average Soil temperature and moisture

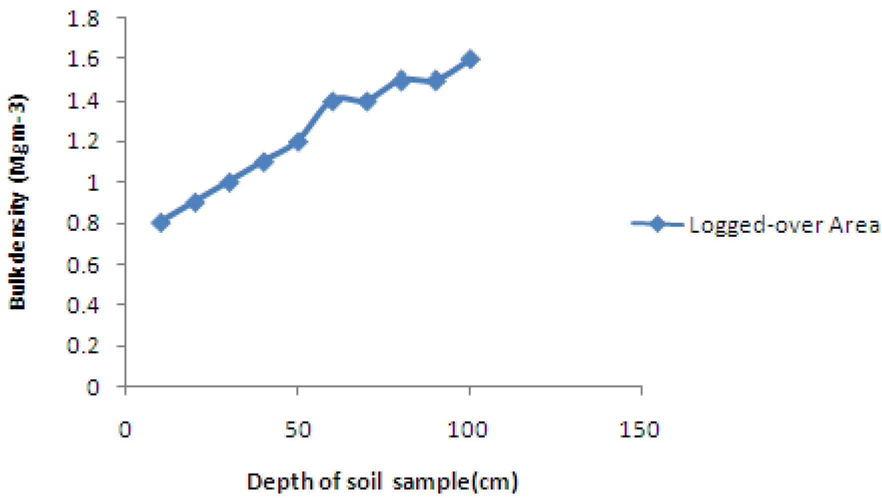

Fig. 3. Earth Bulk Density

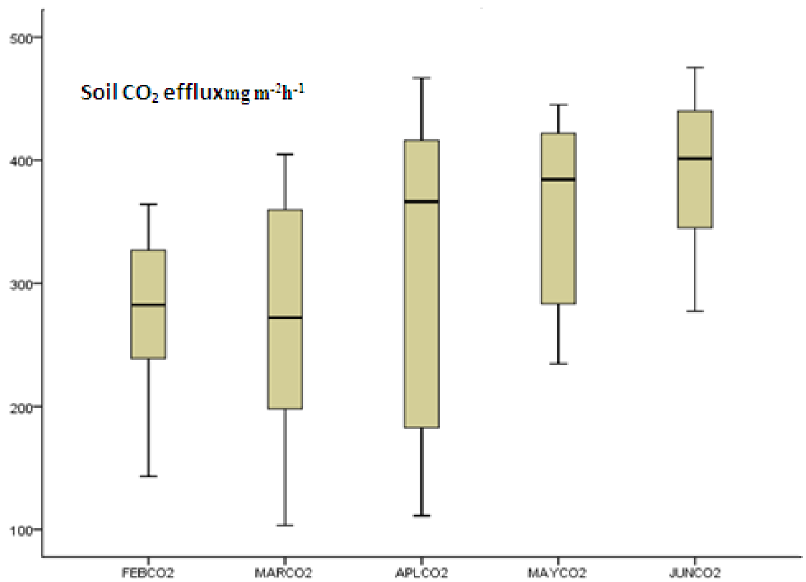

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Fig. 4. Box and whisker plot of Soil CO_2 efflux