OPEN ACCESS

Scholars International Journal of Chemistry and Material Sciences
Abbreviated Key Title: Sch Int J Chem Mater Sci
ISSN 2616-8669 (Print) |ISSN 2617-6556 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: http://saudijournals.com

Original Research Article

Relationship between Carbon Dioxide Emissions and Physicochemical Properties of Wetland Soil at Oguta Lake, Imo State, Nigeria

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DOI: 10.36348/sijcms.2021.v04i05.002 | **Received:** 12.04.2021 | **Accepted:** 17.05.2021 | **Published:** 02.06.2021

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Abstract

Wetlands play significant role in climate change contributing about 5% of the global Carbon dioxide (CO_2) emission through respiration which is being thought to be influenced by the soil properties. In this study the aim is to establishing relationship between wetland soil physicochemical properties and CO_2 respiration from Oguta lake point one. Standard methods were used to determine the soil properties and an AZ 77535 CO_2 gas analyzer held at arm's length was used to determine the concentration of CO_2 at sample location. Mean results showed pH (5.03), temperature (28.16 ^oC), electrical conductivity (108.56 uS/cm), moisture content (17.83 %) and organic matter (1.35 %). Mean weekly [CO_2] concentrations (564 ± 13.5 to 580.72.2 ± 13.03 ppm) were higher than mean around the world (370 ppm) and higher all sites around the lake including the control site (425 ± 2.5 to 438.2 ± 2.0 ppm). There was positive relationship with [CO_2] and R^2 values of (0.262), (0.370), (0.304), (0.294) and (0.056) respectively were observed. This confirms that the respiration of CO_2 is influenced by the soil properties. An increase in soil properties reflected an increase CO_2 concentration. Results add to information on how soil properties can be modified to reduce soil respired CO_2, thereby reducing wetland contributions to global warming.

Keywords: Climate change, Correlation, Green House Gases, Wetland, Soil respiration.

INTRODUCTION

Wetlands are important aspects of the physical environment in contributing significantly to the climate moderations [1, 2]. They are capable of sequestering and storing carbon through photosynthesis and accumulation of organic matter in soils, sediments and plant biomass. Thus wetlands play an important role in regulating exchanges of greenhouse gases with atmosphere. Some researchers regard wetlands as sinks for carbon and nitrogen and sources for methane and sulfur compounds, but situations vary from place to place, time to time and between wetland types [3,4,5,6].

Wetlands can now be defined as a land area that is saturated with water, either permanently or seasonally [7]. Wetlands are terrestrial or semi-terrestrial ecosystems characterized with low drainage quality, slow water and seldom standing water body filled with soil [8]. These conditions enable aerobic and anaerobic respiration in the soil influencing the cycling of carbon, hydrogen, nitrogen and oxygen, and the solubility of phosphorus, thus contributing to the chemical variations in its wetland water composition. Under conditions of a fluctuating water table, mineral soils may exhibit a variety of contrasting colors within the soil profile. Carbon has been fingered the main nutrient cycled within the wetlands. Biogeochemical process in wetlands is determined by soils with low redox potential [9].

The role of wetlands in carbon sequestration and storage has generally been under-estimated. As depositional areas; wetlands can store carbon-rich organic sediments. Under anaerobic conditions, wetlands can also produce greenhouse gases (GHGs) such as methane and nitrous oxide, though this is limited in saline conditions. Clearing or drainage of wetlands can also lead to large losses of stored organic carbon which leads to increase atmospheric carbon dioxide [10, 11].

This switching between sink and source GHGs can be a natural process due to seasonal or other factors or can be affected by human management. Negative feedback mechanisms due to climate change may undermine the sequestration potential of wetlands, for example, by increasing the incidence and severity of fires and droughts [12, 13]. During photosynthesis, carbon from atmospheric carbon dioxide is transformed into components necessary for plants to live and grow. As part of this process, the carbon present in the atmosphere as carbon dioxide becomes part of the plant: a leaf, stem, root, etc. Increasing carbon dioxide levels within the atmosphere will influence global nutrient cycling, yet it is difficult to predict what those interactions might be [14].

CO_2 is naturally captured from the atmosphere through biological, chemical, or physical processes. Artificial processes have been devised to produce similar effects, including large-scale, artificial capture and sequestration of industrially produced CO_2 using subsurface saline aquifers, reservoirs, ocean water, aging oil fields, or other carbon sinks. Carbon dioxide being the most abundant carbon oxidation product can be generated by a lot of ways, below is two ways it can be generated from wetlands. During acetothropic methanogenesis the end product is methane and carbon dioxide. Another is the decomposition of organic matter which leads to production of methane. When oxidized methane yields carbon dioxide and water as end product [15].

CO_2 and CH_4 emission causes global warming due to their ability to absorb solar radiation. The global warming potential (GWP) of CH_4 is 25 times greater than that of CO_2 on a 100-year timescale and high emissions of CH_4 can therefore have disproportionately adverse effects on the climate. Due to the increasing concern of GHGs emissions and global warming, it is important to gain more knowledge about the factors affecting CO_2 emissions in different wetland systems, and understand how the balance might be affected by management actions. Previous work has shown that environmental factors like water table, soil temperature, salinity, and vegetation biomass and type may have strong controlling effects on greenhouse gas emissions from wetlands [16, 17]. Decomposition of organic matter in wetland soil is strongly dependent on temperature, and therefore, CO_2 emissions from decomposition processes tend to increase with increasing soil temperature [18]. The optimum temperature for methaniogenesis is around 20–30° C, depending on the community of methanogenic bacteria [19]. Aerobic decomposition of organic matter emits CO_2. It can therefore be difficult to predict gas emissions under field conditions, as both soil temperatures and water tables may be subject to large seasonal variations.

The presence of vegetation affects CO_2 fluxes primarily by photosynthesizing and by increasing the total ecosystem respiration. However, the vegetation may also affect CH_4 emissions. Oxygen released from roots create aerobic microsites in the rhizosphere, which favors CH_4 oxidation by aerobic methanotrophs. On the other hand, a high primary production also increases the available carbon substrate for methanogens via biomass decomposition and root exudation and can thus lead to higher CH_4 emissions. Acute saltwater intrusion to freshwater wetlands has been reported to increase soil respiration and lead to elevated CO_2 emissions [20]. Although many factors are known to influence CO_2 emissions from coastal wetlands, it is still unclear which factors are most important under field conditions when they are all acting simultaneously.

Knowledge of the interactive effects of the factors driving greenhouse gas emissions is a prerequisite to being able to manage wetlands in a way that minimizes greenhouse gas emissions, and to predict the effects of future climate change on greenhouse gas emissions from wetlands. In other to understand the effect of soil properties on CO_2 emission the following objectives of study were identified: to characterize the soils at the banks of Oguta lake, to determine the emission CO_2 content in the wetlands in Oguta lake in Imo state and to correlate the CO_2 on the soil properties.

MATERIALS AND METHODS

Field and laboratory experiments were carried using standard methods. Field experiments involved physical parameters such as temperature, electrical conductivity, pH and CO_2 concentrations, while laboratory experiments included moisture content, organic matter and ash content. These methods are briefly described as physicochemical properties and were determined using standard methods [21].

Study Area

Oguta Lake is one of the natural water resources of non-marine habitat located in alow-lying (elevation <50 m) platform. The lake precisely lies between latitudes 5°41´N and 5°44´N and longitudes 6^{o}45´ E and 6°50´E in the equatorial rainforest belt of Nigeria. Oguta Lake is a very small lake compared to man-made and natural lakes in Nigeria like Lake Chad, Kainji and Tiga Lakes. It is also the largest freshwater system in south eastern Nigeria. Oguta Lake is of great importance to both the Imo state government of Nigeria as a focal point for sporting, research, tourism development, and to the local population, it is their main source of domestic water supply. Lake is also used for recreation, fishing, transportation and sand mining activities. Oguta Lake lies within the Benin Formation consisting of continental sands with traces of clay/shale and some isolated units of gravel, conglomerate and sandstones. Surface geology of Oguta Lake area using road cuts and low hills revealed that it consists of ferruginized sands which are occasionally massively bedded and pebbly.

Determination of Soil Physicochemical Parameters

Soil Temperature (oC) was measured by use of Soil Gardner's thermometer by inserting the bulb end of the thermometer into the soil at a depth of 4-6cm for 5mins and readings was recorded. The pH of the soil samples were determined using Jenway 3510 pH Meter, which was calibrated with buffers 4 and 7. By dissolving one capsule of each buffer in 100 ml of distilled water. Electrical conductivity was determined using Hanna H18733 EC meter in µS/cm. The apparatus was calibrated using KCl. 50 g of the dried soil sample was weighed into a beaker and 100mls of distilled water was added, vigorously shaken to allow separation of the sediment sample and kept to stand. The EC probe was introduced into the mixture for 60 seconds and value recorded. The moisture content (%) was determined by weighing 10g of the sample into a porcelain dish (which was previously weighed (Wd), then 2 hours placed in the oven at 105 ^{o}C for 2 hours until constant weight Y2. The difference in weight is the moisture in the soil and is calculated using the formula according to [21]. Organic matter (%) content determination was done using the weight loss on ignition method. The oven dried sample after determination of the moisture content was placed into a muffle furnace at 500oC for 5 hours. The OM content was then determined using these calculations according to [22].

Determination of CO_2 Emission

AZ 77535 CO_2 gas analyzer instrument was used to determine the CO_2 concentration emitted from the soil. The gas analyzer gives automatic analysis of sample of ambient air with the use of the physical properties that renders continuous output signal to the analyzer which returns the value of the CO_2, which was read from the screen of the digitized AZ 77535 CO_2. The instrument which was held at arm length and about 10 cm above the soil is used to obtain the concentration of CO_2 emitted in the soil. This was done for morning, afternoon and evening for five days in a week for seven weeks in the dry season of 2015.

STATISTICAL ANALYSIS

Correlation analysis and analysis of variance were used to check for correlations and significant differences in concentrations of CO_2 emitted from soil and the soil properties. Graph, mean and standard deviation was also used were appropriate and result expressed as mean ±SD from n =5. Variability was calculated as SD divided by mean multiplied by 100. According to Verla et. al, [23] low variability is when CV < 20 %.

RESULTS AND DISCUSSIONS

The physicochemical parameters of soil are summarized in table 1 which is very important in the determination of its productive capacity and effect on the CO_2 respiration from the soil.

Table-1: Weekly Average of CO_2 concentrations at the five sampling points

Week		CO_2 (ppm) and variability amongst sampling sites						
	A	B	C	D	E	Mean± SD	VS	Control
1	589±11.7	571.3±3	574±49	578±15.9	587±22.5	579.86 ±8	1.35	437.86±4
2	578.3±19	570±9.6	568.7±8.6	567.7±8.1	566.3±10.1	570.2±4.7	0.83	438.2±2
3	564.7±12.7	564±6	567±8.9	577±28.6	562.3±6.8	567±5.84	1.03	425±2.5
4	592.3±28.7	593.7±15	582±27.7	563.3±10.4	572.3±10.4	580.72±13	2.24	452±1.6
5	567.3±12.2	579±21.3	574±40	547.7±12.5	552.7±15.7	564.14±13	2.40	434±2.0
6	557.3±15.5	562.7±24	577.7±32	584.7±38.2	579±21.5	572.28±12	2.04	436.5±2
7	557.3±15.5	562.7±24	577.7±32	584.7±38.2	579±21.5	572.28±12	2.04	428±2.5
	Physicochemical parameters of the soil from the banks of the lake							
pH	4.06	4.24	7.36	4.35	4.60	5.03	1.37	6-5
Temp	28.3	28.1	28.0	28.2	28.2	28.16	0.11	29.5
EC.	104.0	111	107	106.2	114.6	108.56	4.22	126
Moist	18.14	12.6	20.2	17.2	21	17.83	3.3	8.2
OM	1.47	1.7	0.8	1.6	1.2	1.35	0.36	0.7
Ash	2.8	3.1	3.2	2.8	3.4	3.06	0.26	1.4

SD- Standard deviation, VS- Variability among sites, Moist-moisture content, Mean±nSD for n=3

Table 2: Pearson's correlation for the CO_2 concentrations for the various sampling points

	A	B	C	D	E
A	1				
B	0.7338	1			
C	0.1541	0.4812	1		
D	-0.3434	-0.6995	0.0298	1	
E	0.1807	-0.2291	0.4184	0.7590	1

Physicochemical Properties and CO_2 Respiration

The pH of the soil ranges from 4.06 to 7.36 with mean value of 5.03 which shows acidic soils as seen in Table 1. The pH is weakly acidic and plays an important role in the metal bioavailability to plant, toxicity and leaching capacity of soil to surrounding areas [24]. However, point C has a pH of 7.36 which is weakly alkaline. The mean pH showed positive correlations (≤1.000) with variations of respired CO_2 recorded for the various sampling points.

Temperature indirectly affects the soil biota by affecting physico-chemical properties such as diffusion & solubility of nutrients, mineral weathering and evaporation rates. Furthermore, it affects almost all aspects of respiration processes. Temperature will increase respiration exponentially to a maximum, at which point respiration will decrease to zero when enzymatic activity is interrupted. Root respiration increases exponentially with temperature in its low range when the respiration rate is limited mostly by the Tricarboxylic Acid cycle. At higher temperatures (≥35 ^oC) the transport of sugars and the products of metabolism become the limiting factor. At temperatures over 35 degrees Celsius, root respiration begins to shut down completely [9]. However, most of the microorganisms that causes CO_2 emissions from soils operates optimally between 20 ^oC and 40 ^oC, with the current study falling within the range (28.16 ^oC) (Table 3.0) which showed positive correlation (0.370) with respired CO_2 in the soils in all the sampling points (A to E) as seen in figure 3. Temperature increases lead to greater rates of soil respiration until high values retard microbial function; this is the same pattern that is seen with soil moisture levels (figure 1). Therefore, to prevent CO_2 emissions from soils, the temperature should be kept < 20 degrees and > 40 degrees. Temperature measurements were within international standards.

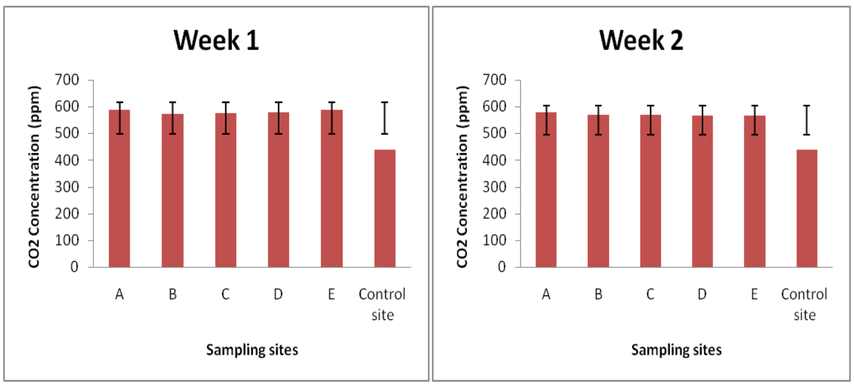
The electrical conductivity of the soil samples analyzed ranges from 104.0 to 114.6 (Table 3), which falls within the range of international standard. The electrical conductivity correlates positively (0.304), indicating increasing CO_2 respiration as electrical conductivity increases (figure 1). Additionally, it is a measurement of the dissolved material in an aqueous solution, which relates to the ability of the material to conduct electrical current through it.

The moisture content of the soil samples analyzed (table 3) ranges from 12.6 % to 21 %. This indicates the amount of water present in the soil. The moisture obtained in this study also correlates positively (0.204) with the CO_2 recorded in this study (figures 1 and 2). Soil CO_2 respiration is low in dry conditions and increases to a maximum at intermediate moisture levels until it begins to decrease when moisture content excludes oxygen. This allows anaerobic conditions to prevail and depress aerobic microbial activity. Studies have shown that soil moisture only limits respiration at the lowest and highest conditions with a large plateau existing at intermediate soil moisture levels for most ecosystems [17]. Many microorganisms possess strategies for growth and survival under low soil moisture conditions. Under high soil moisture conditions, many bacteria take in too much water causing their cell membrane to lyse, or break. This can decrease the rate of soil respiration temporarily, but the lysis of bacteria causes for a spike in resources for many other bacteria. This rapid increase in available labile substrates causes short-term enhanced soil CO_2 respiration [15].

The soil organic matter is a reservoir of nutrients that can release to the soil and it improves soil structure. The organic matter content of the soil obtained in this study ranges from 0.8 to 1.7 with mean value of 1.47.

Ash content is a measure of mineral content of soil. It is proposed that high mineral content indicates high metal content which could hinder microbial action on organic matter, thereby, reducing CO_2 emissions. Ash content in Oguta lake soil was highest at site E and lowest at site A, these values are typical for soil around the world.

Variations of CO_2



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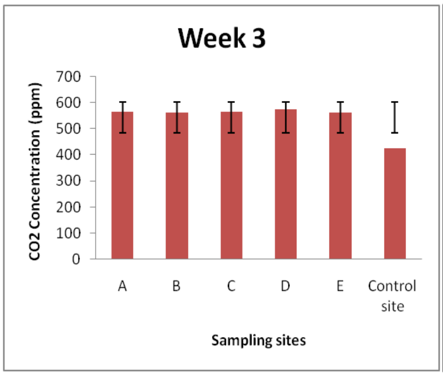

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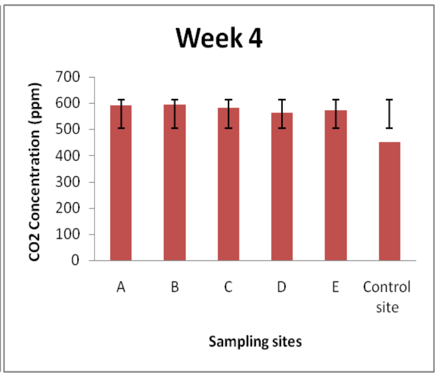

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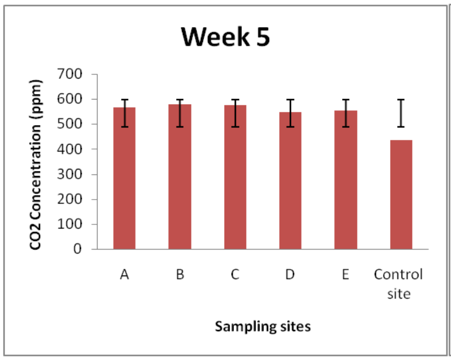

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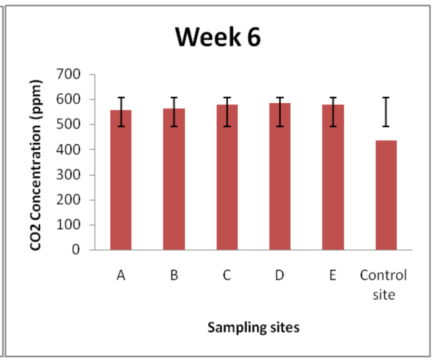

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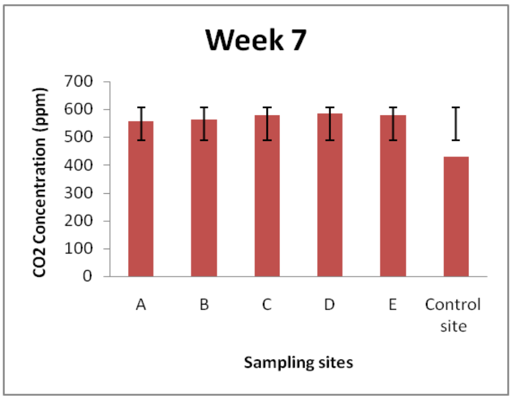


(g)

Fig-1(a) - (g): Bar charts of weekly CO_2 concentrations showing error bars with standard deviations

The variation of the CO_2 emission concentrations for seven weeks is shown in figure 1(a) - (g). One factor ANOVA showed that there was no significant difference (P>0.05) between concentrations of respired CO_2 from the soil at various sampling point in Oguta point 1 in seven weeks, since the calculated value (0.07829) < critical value (2.689628). However, point C had the highest respiration in seven weeks, while point E was lowest. Ranking the order points C>A>D>B>E respectively in descending order. Furthermore, there was a positive correlation between points A, B, C and E (0.15 to 0.73) as seen in table 3.4. Additionally, points A and D, D and B, then C and B have negative correlations of -0.34, -0.699, and – 0.23 respectively.

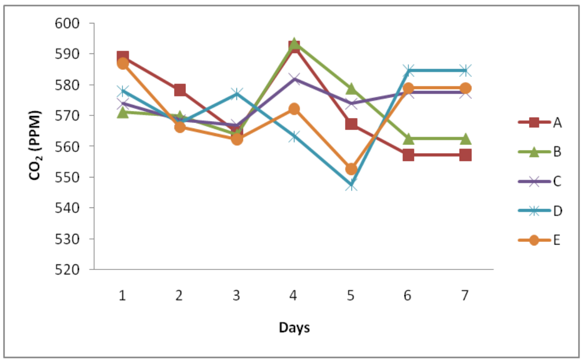
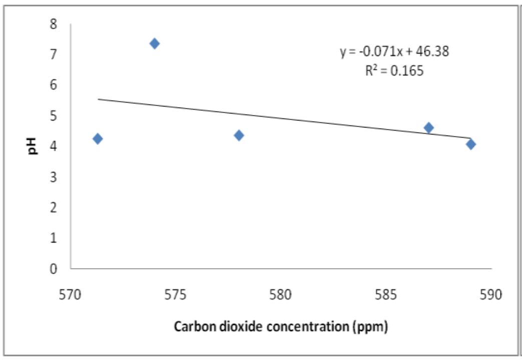


Fig-2: Plot showing the weekly variation of CO_2 (ppm) with days for various sites

Variability of CO_2 concentrations for the period of study showed little variations ranging from 0.87 % in the second week to 2.4 % in the third week. It could be said that week 6 and 7 had same variability. These little variability could mean good instrument use or that no major change in the soil properties that affects CO_2 emission from wetlands.

Regression plots of CO_2 concentration and soil properties showed a wide variation in the trends with most plots showing positive correlations.



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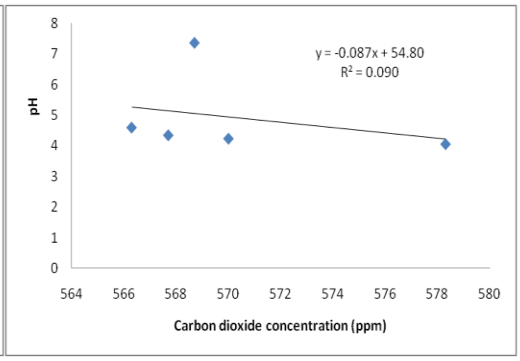

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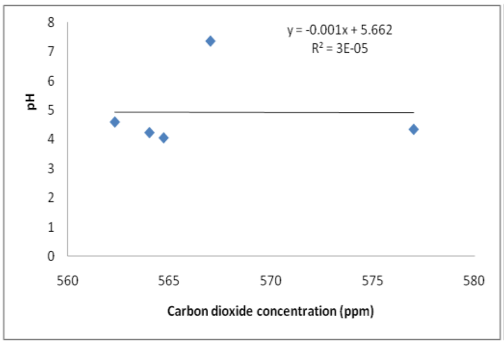

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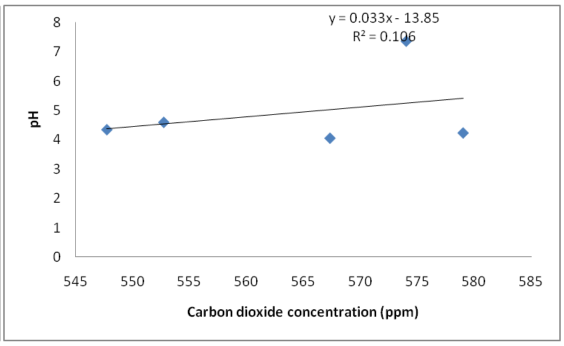

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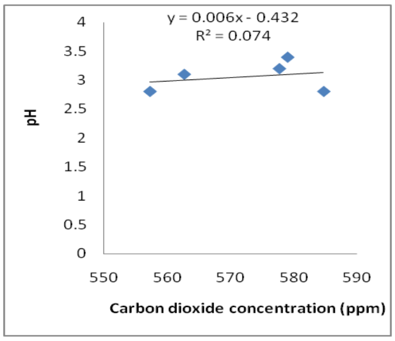
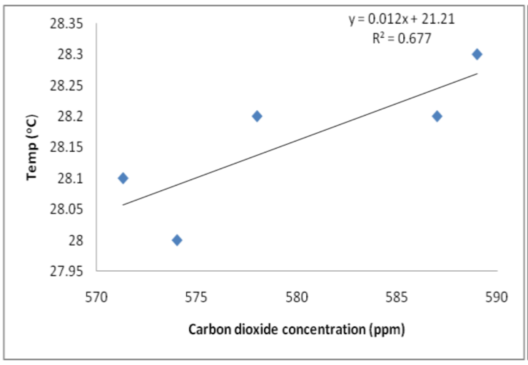


(e)

Fig-3(a)-(e): Regression plots with trend line for pH against CO_2 concentrations



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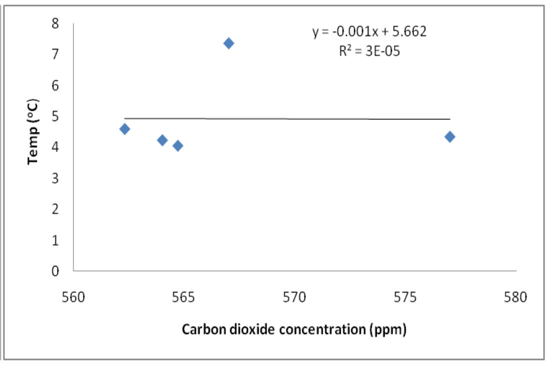

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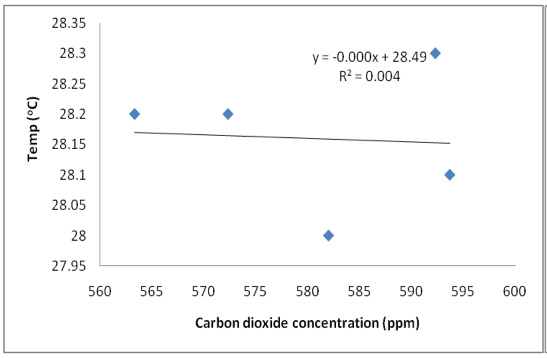

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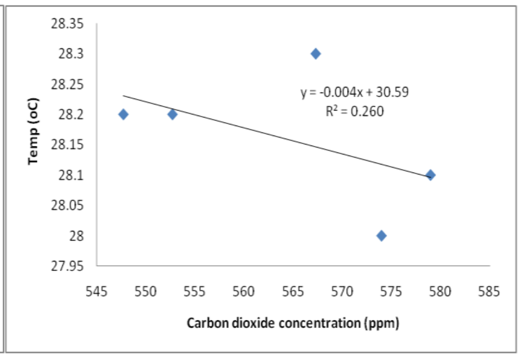

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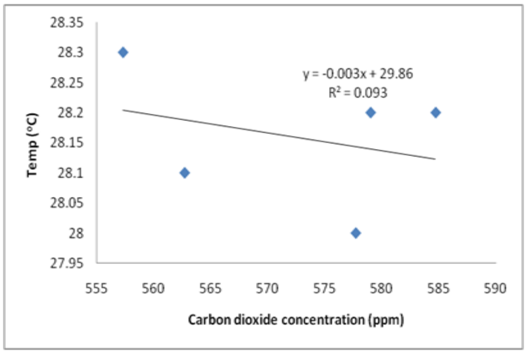
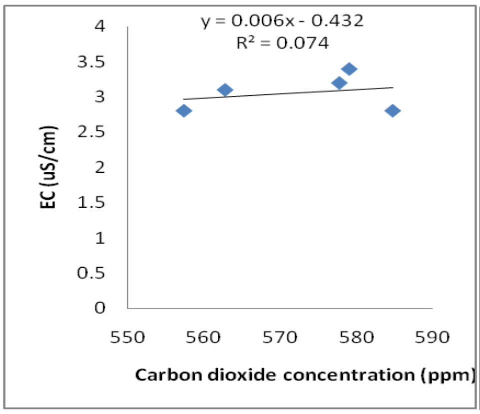


(e)

Fig-4(a)-(e): Regression plots with trend line for Temperature against CO_2 concentrations.



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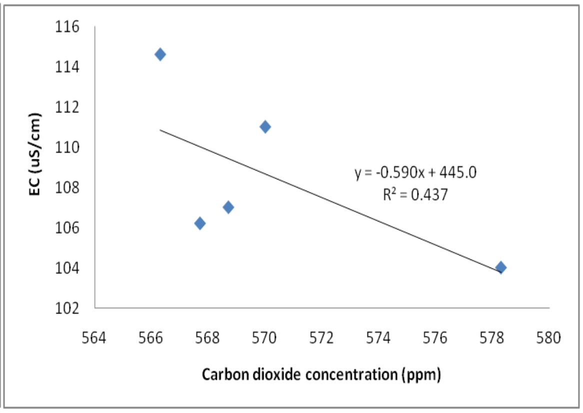

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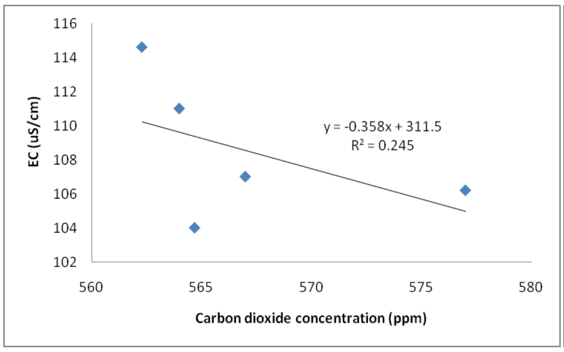

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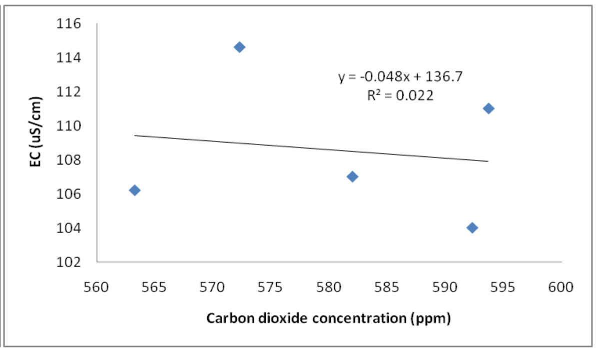

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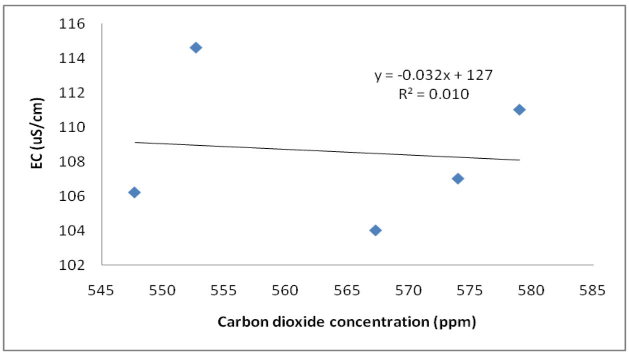
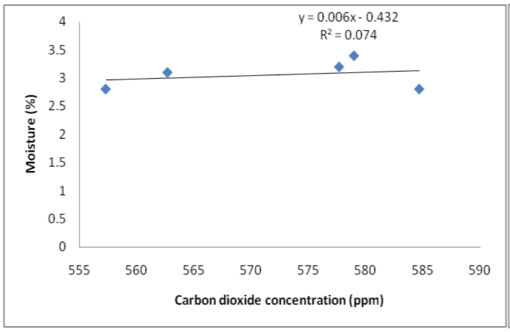


(e)

Fig-5(a)-(e): Regression plots with trend line for Electrical conductivity against Carbon dioxide concentrations



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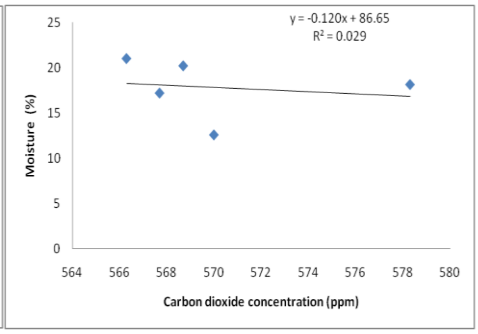

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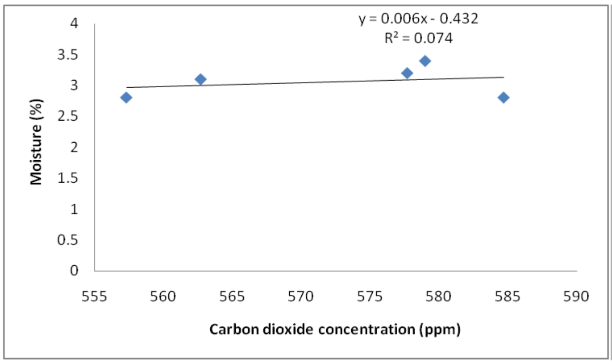

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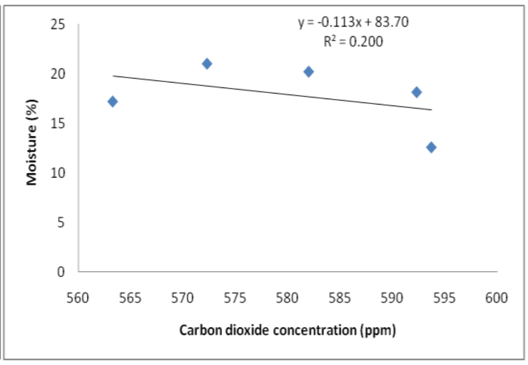

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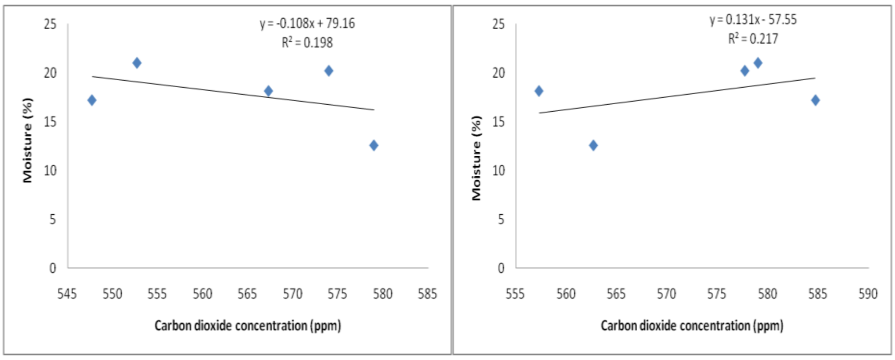
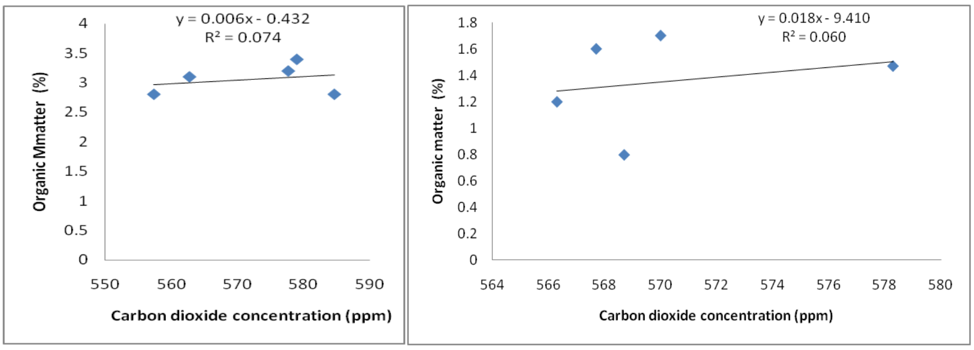


(e) (f)

Fig-6(a)-(e): Regression plots with trend line for moisture against CO_2 concentrations



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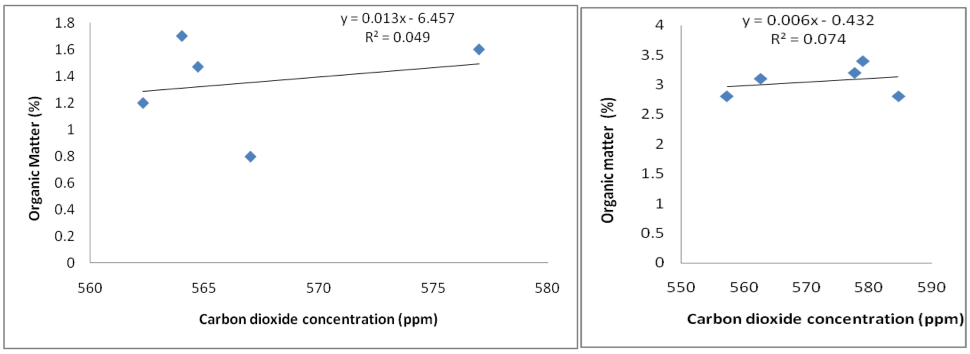
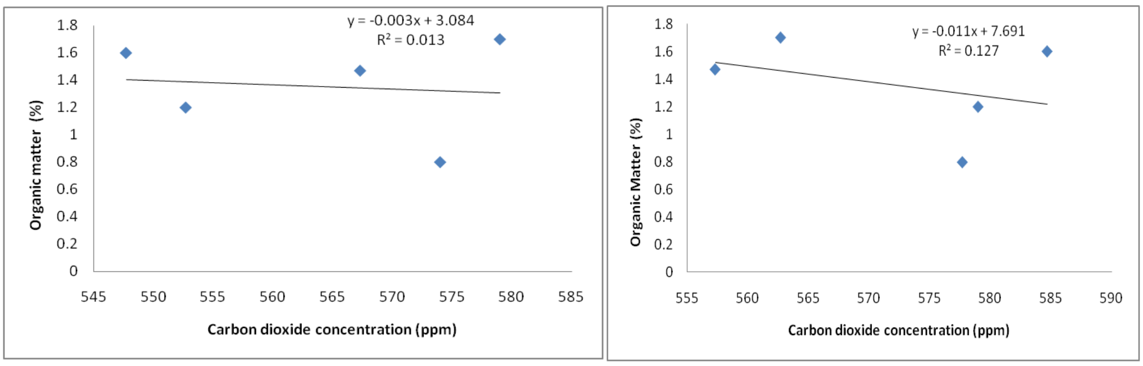


(b) (d)



(e) (f)

Fig-7(a)-(f): Regression plots of organic matter and CO_2 concentrations

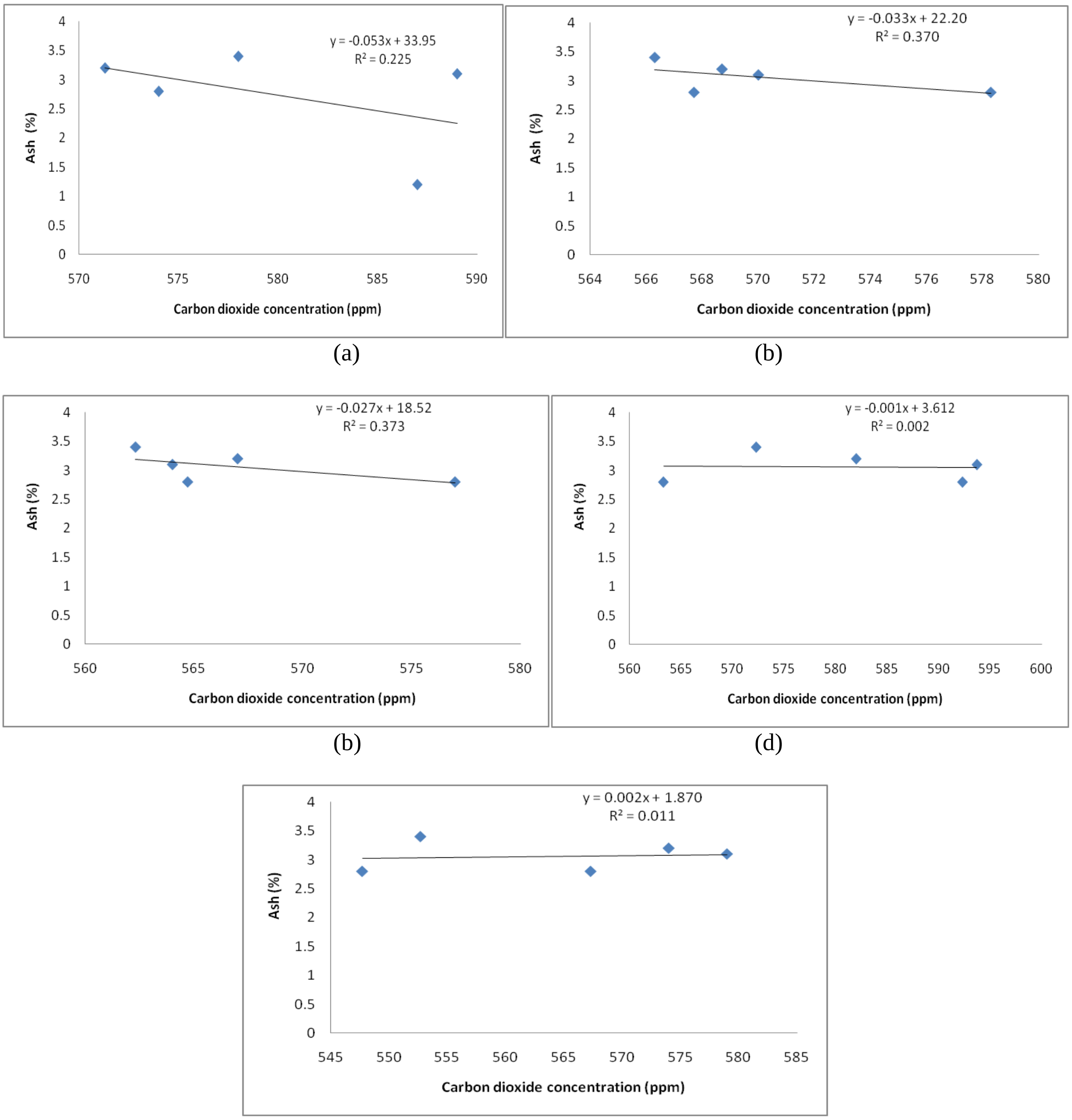


Figure 8(a)-(e): Regression plots of ash content and CO_2 concentrations

However, mean soil properties correlated positively with the average CO_2 concentrations obtained from weekly results. This is expected as has been reported by other researchers.

Table-4: Summary of trends in behavior of physicochemical properties and CO_2 concentration

Relationship	A	B	C	D	E
pH-CO_2	-	-	Slight	Slight	Slight
Temp-CO_2	+	Slight	-	-	-
EC-CO_2	Slight	-	-	-	-
Moisture-CO_2	Slight	Slight	Slight	-	-
OM-CO_2	+	+	+	-	-
Ash-CO_2	-	-	-	Slight	Slight

CONCLUSION

All site had regression equations with little slope. Ash content, temperature and EC showed more negative correlations than positive ones; meanwhile OM showed much positive correlations than any other parameter. From this present study, there's a positive correlations which showed positive relationship between CO_2 respiration from wetland soils and this clearly indicates that CO_2 respiration can be influenced greatly by soil physicochemical properties.

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