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EVALUATION OF CARBON DIOXIDE EMISSIONS IN SOIL UNDER DIFFERENT REDOX POTENTIALS

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ABSTRACT

Carbon dioxide (CO₂) is a major greenhouse gas (GHG) contributing about 60% to the total GHGs in the atmosphere. According to statistics, 70% of the earth soils are waterlogged soil (reduce condition) which has effect on CO₂ fluxes. Hence, the experiment set out is to investigate how CO₂ is being emitted under different soil redox potential. Three locations were used for the study. The sites were categorized into Oxidized soil (Eh > 300), moderately reduced soil (-100 to 300) and reduced soil (redox Eh < -100). Data collected included the emissions of CO₂ on each of the redox statuses. CO₂ emission was monitored using gas entrapment method and it was done in the morning, afternoon and evening. Also cumulative trapping was done for 24 hours. Graph and bar chart were generated using Microsoft excel 2016 to present results. The result showed that the emission of CO₂ is highest under Oxidized soil and low in moderately reduced soil and reduced soil. Also emission was found to be highest in the afternoon compared to other times of the day. It was concluded that there is emission of CO₂ in the three locations however; Oxidized soil has the highest emission of carbon dioxide.

Keyword: CO₂ emission, greenhouse gas, redox potential, oxidized, reduced

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INTRODUCTION

Carbon dioxide (CO₂) is an important greenhouse gas accounting for 60% of the total greenhouse effect. Soil is one of the sources for atmospheric CO₂, in the invent of growing threat of global warming due to greenhouse gas emission, reducing CO₂ emission by sequestering C in the soil is of prime importance. Soil management practices like increasing soil organic carbon content, reduced tillage, residue incorporation, improving soil biodiversity, micro aggregation and mulching can play an important role in sequestering C in soil (Monika et al., 2002)

In the last few decades there has been an increase in the emission of naturally occurring, radioactively gases like carbon dioxide (CO₂) methane (CH₄) and nitrous oxide (N₂O): popularly known as greenhouse gases. These gases trap the outgoing infrared radiation from the earth's surface within the earth's atmosphere. This process, generally referred to as the greenhouse effect, adds to the net energy input of the lower atmosphere and leads to regional and global changes in climatic parameters like temperature and rainfall. Human health, terrestrial and aquatic ecological system, agriculture, forestry, fisheries, and water resources are sensitive to these changes in climate. Among the greenhouse gases, CO₂ is the most abundant, accounts for 60% of global warming (IPCC, 2014). The concentration of CO₂ in the atmosphere has increased from 280 ppmv at the beginning of the industrial revolution to the present-day value of 366 ppmv (Keeling and Whorf, 2005). This increase is attributed to the anthropogenic activities, including fossil fuel burning, deforestation, emission from automobiles, forest fires and agriculture, particularly crop production. Scientists working on global warming and climate change have recently focused attention on soil as a major source and sink for atmospheric CO₂ (Le Quéré et al., 2018). Soil contributes 20% of the total emission of CO₂ to the atmosphere through soil respiration (Davidson and Janssens, 2006). Besides disturbing the earth's heat badge, emission of CO₂ from the soil results in diminution of soil organic C pool, soil fertility and productivity (Paustian et al., 2016).

The world's soils hold about twice (1400-1500 Gt of C) as much as carbon as the atmosphere (Jobbágy and Jackson, 2000). Carbon stored in agricultural soil is 170Gt, while the entire vegetation contains 550 Gt C. Emission of CO₂ due to deforestation is considered to be a major source for atmospheric CO₂. Soil and vegetation together exchange 100 Gt of C per year with the atmosphere and soil respiration alone contributes 50-75 Gt of C per year (Canadell et al., 2007). The total C lost as a result of bringing land under crop cultivation the world over has been estimated at 50 Gt of C, in which the contributions of temperate grassland and tropical forest soils were substantial (Houghton, 2003). Carbon dioxide is released from soil through soil respiration, which includes three biological processes, which are; microbial respiration, root respiration and faunal respiration primarily at the soil surface or within a thin upper layer where the bulk of the plant residue is concentrated, and non-biological process, i.e. chemical oxidation which could be pronounced with higher temperature (Monika et al., 2002). Soil micro floral contributes 99% of the CO₂ arising as a result of decomposition of organic matter, while the contribution of soil fauna is much less. Root respiration, however contributes 50% of the total soil respiration (Subke and Bahn, 2010). Several studies have shown that factors such as soil texture, temperature, moisture, pH, available C (labile and non-labile components of soil organic), and N content of soil influences CO₂ production and emission from the soil. However, none has taken a look at how redox potential of soil can affect the emission of CO₂. Given that microbes which are responsible for different process that releases CO₂ into the atmosphere are themselves affected by soil Redox potential (Dayo-Olagbende et al., 2019). Then it can be hypothesized that soil redox potential or Eh will affect the emission of CO₂ from the soil or could also help in sequestering carbon. Hence this research sets out to evaluate the effect of different soil redox potential on CO₂ emission.

METHODS AND MATERIALS

Study area

The study was carried out at the school farm of the Federal University of Technology, Akure. Three locations within the school with different redox potential were sampled and soil samples were collected from each site.

Establishment and method used

The locations were selected based on their redox potential (Eh) namely; oxidized soil, moderately reduced and reduced soil. This classification is based on the classification of Reddy 2005.

- Oxidized soil has redox potential greater than 300
- Reduced soil has redox potential less than (-100)
- Moderately reduced has redox potential (-100 to 300)

Preparation

Ten millimeters of NaOH solution was added in an empty beaker, and placed in a container already fitted into the soil and then covered to trap the CO₂. The sampling was done in the morning (between 7am to 10am), afternoon (between 12noon to 3pm) and in the evening (between 5pm to 8pm). Also a cumulative trapping was done for 24 hours.

Titration

After three hours of trapping, BaCl of five millimeters was added to the NaOH immediately and phenolphthalein of two drops was added as an indicator.

The burette was filled with HCL and was carefully released to the sample (NaOH, BaCl and the indication) and shaken until a color change was observed.

Gradually, the sample began to change from pink to a colourless form and when the colour was completely pure without any pinky form, the readings were taken and recorded correctly.

This was repeatedly done three times in the same location with the interval of two days' break and the same method was used for the entire site both moderately reduced and reduced soil.

Trapping of CO₂ emission under different soil redox potential for 24 hours

This followed the same process as the previous only that the trapping was done for a duration of 24 hours as against 3 hours. A blank reading was also collected, in this case the NaOH was not allowed to trap any CO₂ while all other procedures were followed.

Calculation of the readings

The formular used in calculating the readings was (B-V) * (NE).

Where B is the blank reading

Where V is the entrapped reading (final reading – initial reading)

Where N is the molarity of NaOH (0.5)

Where E is 6

The final answer of the readings was recorded and taken for statistical analysis.

Statistical analysis

Data collected were subjected to analysis of variance using SPSS version 12 while means were separated using Tukey HSD at a probability rate of 5%. Graphs and charts were generated using Microsoft excel 2016 edition.

Conversion of CO₂ emission from centimeter to hectare

This was done for the emission of CO₂ under different soil redox potential for 24 hours. The area of the container used for trapping CO₂ was calculated and then converted to hectare. It shows the amount of CO₂ emitted in one hectare. Below is the fomular used for converting to hectare

$$\text{Emission (ha)} = \frac{\text{Emission (g)}}{\text{Surface Area of container}} \times 10,000$$

RESULT

Pre-experimental soil analysis

Table 1 shows the result of the soil taken from the site after analyzing the soils in the laboratory. The textural class of the oxidized soil is sandy loam clay while for moderately reduced is loam and reduced soil is sandy loam. The redox potential of the oxidized soil is 320, for moderately reduced soil is 127 and reduced soil is -310. The pH of the oxidized soil is alkaline, moderately reduced soil is acidic and the reduced soil is alkaline.

Table 1: Pre experimental result of the soil

Parameters	Size 1	Size 2	Size 3
Eh class	Oxidized	M. reduced	Reduced
Eh(mv)	320	127	-310
Sand	64.47	35.54	51.20
Silt	15.09	40.00	19.50
Clay	20.04	21.16	29.30
Textural class	Sandy loam clay	Loam	Sandy loam
pH	8.69	6.52	7.28

The emission of CO₂ under different redox potential

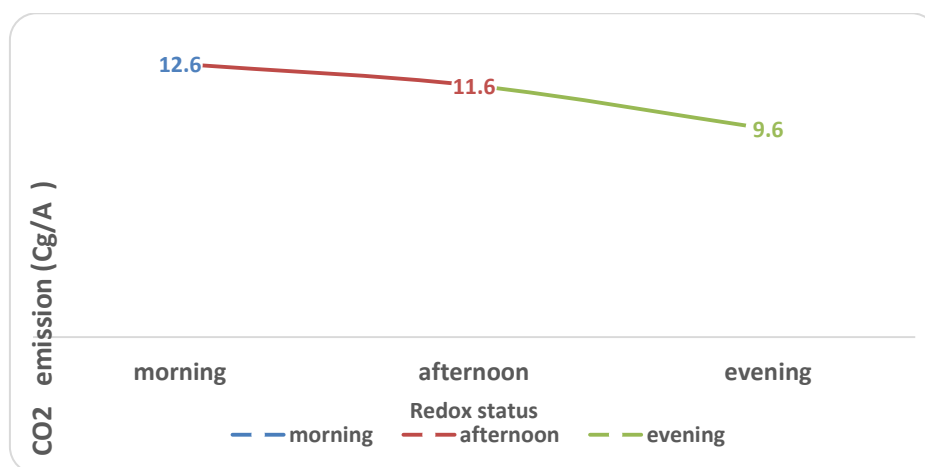
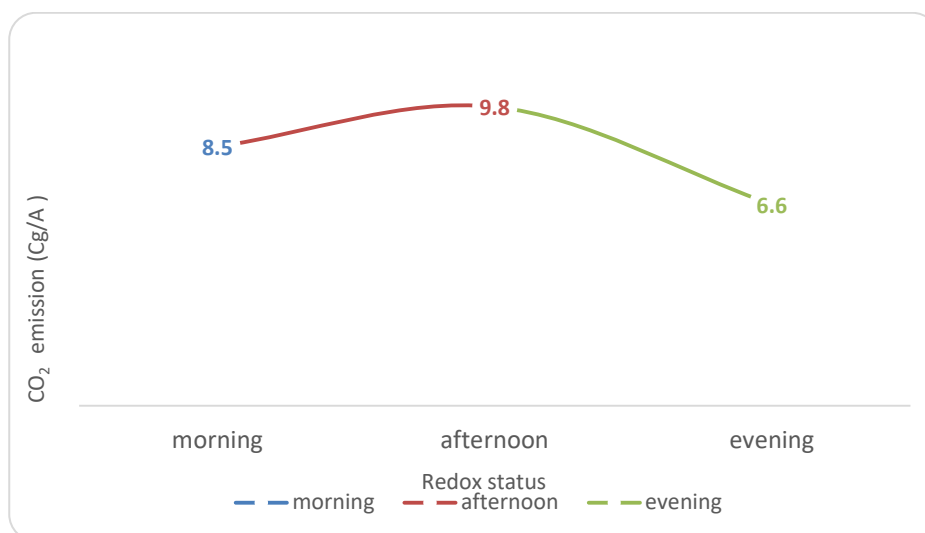
The Oxidized soil recorded the highest value in the morning followed by afternoon and evening as well as 24 hours. Under oxidized soil, the values are as well as follows; for morning the value is 12.6 Cg/A, afternoon's value is 11.2 Cg/A and evening is 9.6 Cg/A. For 24 hours, the value is 200,000 g/ha C. The moderately reduced soil values are as follows; for morning the value is 8.5 Cg/A, afternoon is 9.8 Cg/A and evening value is 6.6 Cg/A. For 24 hours, the value is 172 222 g/ha C. The reduced soil recorded values are as follows; for morning is 6.9 Cg/A, afternoon is 7.2 Cg/A and evening value is 5.7 Cg/A. For 24 hours, the value is 94,444 g/ha C.

Table 2: post experimental result of emission of CO₂ under different soil redox potential

Treatments	Morning Cg/A	Afternoon Cg/A	Evening Cg/A	24 hours g/ha C/day
Oxidized	12.6a	11.2a	9.6a	200,000a
M.Reduced	8.5b	9.8b	6.6b	172,222b
Reduced	6.9b	7.2b	5.7b	94,444c

The emission of CO₂ under different redox potential

Figure 1, 2 and 3 shows the trend line of CO₂ emission under Oxidized soil, moderately reduced and reduced soil respectively. Emission was highest in the morning with the value 12.6 Cg/A , afternoon with the value 11.2 Cg/A and evening with the value 9.6 Cg/A . Moderately reduced soil emission was highest in the afternoon with the value 9.8 Cg/A followed by morning with the value 8.5 Cg/A while Evening recorded the lowest emission of CO₂ with the value 6.6 Cg/A . Reduced soil emission was highest in the afternoon with the value 7.2 Cg/A followed by morning with the value 6.9 Cg/A . It was recorded that emission was lowest in the evening with the value 5.7 Cg/A . Figure 4 shows the emission of CO₂ for 24 hours under different soil redox potential. Oxidized soil had the highest emission as expected with the value 10.9 Cg/A followed by afternoon with the value 9.3 Cg/A and evening recorded the lowest emission of CO₂ with the value 5.1 Cg/A .


Figure 1: The trend line of CO₂ emission under oxidized soil

Figure 2: The trend line of CO₂ emission under moderately reduced soil

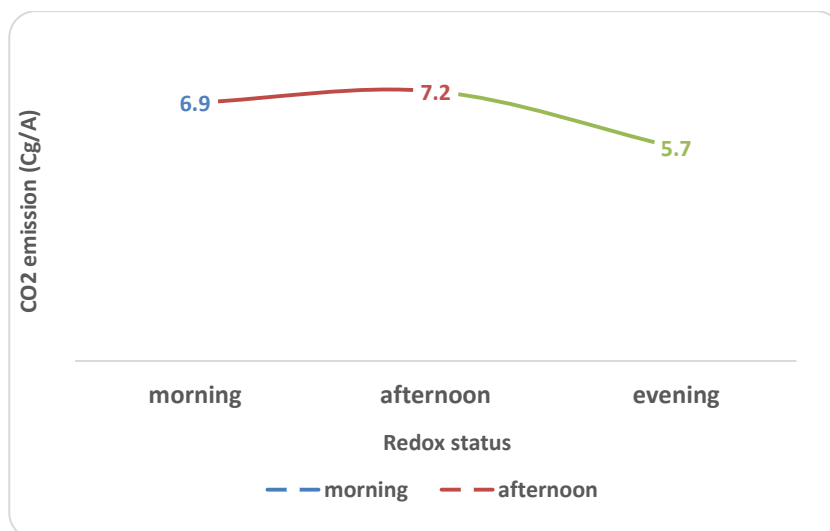


Figure 3: The trend line of CO₂ emission under reduced soil

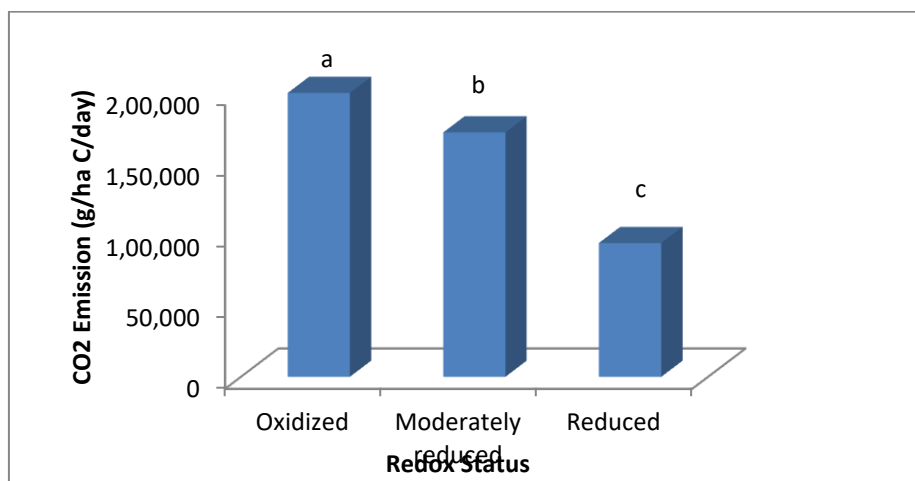


Figure 4: The bar chart of the emission of CO₂ different under soil redox status for 24 hours

DISCUSSION

Effects of soil redox potential on CO₂ across the day

Across the day, the result revealed that oxidized soil recorded the highest CO₂ emission, followed by the moderately reduced soil and then the reduced soil. Oxidized condition promoted the free movement of oxygen within the soil matrix which promotes the activities of soil microbes allowing them to carry out activities such as decomposition and respiration (Batjes, 2014). These activities increase the rate of CO₂ emission.

The morning is a crucial period for soil respiration and CO₂ emissions due to several reasons. Firstly, microbial activity tends to be highest in the morning as microorganisms become more active after a period of decreased activity during the night. This increased microbial activity leads to higher rates of respiration and subsequent CO₂ release (Delgado-Baquerizo et al., 2014). Additionally, temperature plays a crucial role in regulating soil respiration rates. In the morning, as temperatures rise, microbial metabolic rates increase, which can enhance the decomposition of organic matter and the release of CO₂ (Davidson et al., 2002).

Moreover, the morning period is characterized by increased availability of substrates for microbial respiration this is because during the night, root exudates and organic matter inputs from plants accumulate in the soil, providing a fresh supply of carbon substrates for microbial consumption (Luo et al., 2001). This abundant energy source in the morning stimulates microbial respiration and leads to higher CO₂ emissions.

Across all redox potentials sampled, the highest CO₂ emissions occurred in the afternoon. Several factors can contribute to this observed pattern, including microbial activity, temperature, and substrate availability (Fierer and Schimel, 2003).

However, reduced soil emitted the lowest CO₂ across all redox potential. This could be attributed to lesser amount of oxygen available in the soil due to water logging. The presence of the water will not only reduce the air content but also the flow of air in the soil. Aerobic organisms that produce CO₂ during respiration cannot survive under this condition resulting in lower emission of CO₂ (Ström et al., 2003). Temperature is another

important factor influencing soil respiration rates (Davidson et al., 2002). As temperatures rise throughout the day, microbial metabolic rates increase, leading to higher rates of organic matter decomposition and CO₂ release. From the result emission was highest in the afternoon resulting from higher temperature compared to the morning and evening (Wang et al., 2010). Additionally, availability of carbon substrates for microbial respiration can also impact CO₂ emissions. Organic matter, such as root exudates and fresh litter, accumulate in the soil throughout the day (Luo et al., 2001). Microbes utilize these carbon substrates as a source of energy for respiration. By the afternoon, microbes will have access to these exudates a process that further increases CO₂ emissions (Blagodatskaya and Kuzyakov, 2008).

From the table, the emission of CO₂ dropped in the evening because as temperature decreases in the evening time, microbial metabolic rate decreases, leading to reduced CO₂ production. Additionally, the consumption of available carbon substrates by microbes during the day can deplete the readily available organic matter in the soil, resulting in lower CO₂ emissions in the evening (Sinsabaugh et al., 2013). The end product of organic matter under reduced soil is pyruvate, it does not breakdown completely to form CO₂ (Knorr and Blodau, 2009). This accounts for why the evening recorded the lowest emission throughout compared to morning.

Figure 4 shows that cumulatively, emission was highest under oxidized condition and lowest under reduced condition. This is a resulting effect of all the previously explained phenomenon of microbial activities, temperature and substrate leading to CO₂ emission.

CONCLUSION

The study aims to evaluate the rate of emission of carbon dioxide (a greenhouse gas) from soils under different redox status. The results show that soil redox potential significantly affects CO₂ emissions. Oxidized soil had the highest emissions, while reduced soil had the lowest, highlighting the importance of soil management for mitigating climate change. It can thus be inferred that soils under reduced conditions sequesters more carbon than their oxidized counterparts. Farming activities that increases the presence of oxygen in soil has to be monitored to reduce overall impact on CO₂ emission. Conservation tillage should be encouraged as against conventional tillage as the later can increase CO₂ emission from the soil resulting from increased oxygen supply to the soil.

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