STUDIES ON GREEN HOUSE GAS EMISSIONS FROM RICE FIELD IN RWANDA

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Abstract:

The overall objective of this research is to estimate the Green House Gases (GHGs) emissions in different time of the day and to bring out the time of maximum and minimum GHGs emissions from the rice field. An experiment was conducted to estimate the GHGs emission from the rice fields of Muvumba P-8. Gas collection chambers were installed in 9 plots to collect the greenhouse gases. The gas samples were analyzed in Gas Chromatography and converted its results in to usable form. There was marked difference in the mean CO_2 gas emission among the plots. The overall mean of CO_2 gas emission among the experimental plots was 1950521 µg m-2 h-1. CH_4 gas emission was high at 9 am and the minimum is at 3 pm among the mean gas production. Maximum CH_4 gas emission at 9 am is due to the fact that during night time rice plant takes more CH_4 and release the same due to ambient temperature rise at 9 am. The minimum CH_4 gas emission at 3 pm is due to the fact that rice plant released all its CH_4 during day time around 9 am to 3 pm and there was less CH_4 in the rice plant to release at 3 pm. The mean of N_2O gas emission at 6 am, 9 am, 12 noon and 3 pm of all the experimental plots was found to be 960.86 µg m-2 h-1. The mean N_2O gas emission at 9am was found to be 995.82µg m-2 h-1. The important conclusion from the study is that N_2O gas emission at 6 am and 12 noon are behaving similarly with decreasing trend. It was also found that N_2O gas emission at 9 am and 3 pm are behaving similarly with decreasing trend.

Keywords: Rice field, Green House Gases, emission, marshland

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1. Introduction

Agricultural research is gaining much importance in Rwanda because of the emission of GHGs from wetlands and its negative impact on climate change. Systematic studies were not carried out to estimate the amount of GHGs emission from the wetlands of Rwanda. This will cause the researchers to take the research work of estimating the amount of GHG emission from the wetlands of Rwanda. There is no research data about the effect of diurnal variation and soil condition on the emission of GHGs in Rwanda rice field conditions. Some relevant literature are given. The general trend for continuously flooded rice fields is that emissions increase during the vegetative stage, peak before flowering and rapidly decrease with a short high peak when the field is dried out before harvest**.** But this trend changes with different management practices and climate (Wang and Shangguan, 1995). Parkin and Venterera (2010) stated that sample handling and storage are done using various kinds of equipment (e.g. polypropylene syringes, glass vials with different seals, vacutainers, gas bags, etc.) and over different time periods from 'immediate' analysis to storage over several weeks.

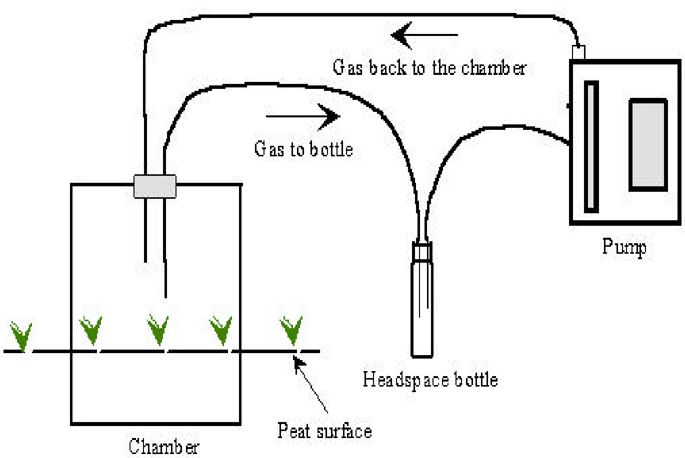

Figure 1 Experimental set up to collect the GHG sample from the field

The circulation between the bottle and sampling chamber was permitted to minimize the

Sander et al., (2014) stated that the common approach to quantify GHG emissions is the 'closed chamber method,' which was first described in the late 1970s. Gas samples are collected from the inside of a gas-tight chamber at certain time intervals. The flux rate is then determined from the concentration change of CH_4, CO_2 or N_2O over time. USDA-NRCS (2018) stated that there is release of carbon dioxide (CO_2) from soil due to soil biological activities (i.e., microorganisms and roots) and decomposition. According to Whalen (2005), wetlands contribute to about 24% of worldwide CH_4 emissions from all sources, and are the largest natural source of CH_4. The position of the water table has a great impact on CH4 emissions, as high water tables favor oxygen reduction and thus low redox potentials, which favors methanogens in the wetland soil. The more oxidized conditions associated with low water tables influence CH4 oxidation by aerobic methanotrophic bacteria, as well as aerobic decomposition of organic matter, both processes emitting CO_2. According to Mitsch and Gosselink, (2007) decomposition of organic matter in wetland rely mostly on temperature, and both CO_2 and CH_4 emissions from decomposition processes seems to increase with increasing soil temperature. Bouwman et al., (2002) stated that sixty percent of man-made N_2O emissions derive from agriculture and these have mainly been attributed to nitrogen fertilizers application. In flooded rice fields, however, N_2O emissions play only a minor role but may strongly increase under different water management practices. Buresh, (2009) stated that nitrous oxide (N_2O) is one of the key greenhouse and ozone (O_3) depleting gas, constituting 7% of the anthropogenic greenhouse effect. On a molecular basis, N_2O has 310 and 16 times higher global warming potential than that of CO_2 and CH4 respectively over a 100-year period

Kayranli(2010) stated that wetlands play an important role in the global carbon cycling as they function both as carbon store in soils and vegetation, and as carbon sources, by releasing CO_2 into the atmosphere. In 2010, atmospheric concentration of carbon dioxide was 370 ppm, meaning that in samples of one million molecules of ambient air we would expect to find, on average, 370 molecules of carbon dioxide and increasing at approximately 1.5 ppm per year. Carbon dioxide is fixed by plants and autotrophic microorganisms through photosynthesis and thereby transformed to organic compounds locked away from the atmosphere, a process called carbon sequestration. Mitsch(2013) stated that wetlands can store organic carbon vectored into the soil for a long time due to the generally slow decomposition rates in anaerobic wetland soils (decomposition of organic matter does however still take place, both through aerobic and anaerobic processes. Aerobic processes are more efficient and mainly form CO_2 as an end-product, whereas anaerobic decomposition is much slower and, along with CO_2, also produces CH_4. Both gasses are known as greenhouse gasses, which cause global warming due to their ability to absorb solar radiation. Dutta and Ghokale (2017) stated that more tillage exposed the soil to atmospheric oxygen, which leads to excess mineralization of organic carbon and emissions of CO_2 from the field. Huifeng Sun et al. (2016) stated the effects of three irrigation levels like traditional normal amount of irrigation 100%, 70%, and 30% of the normal amount on two rice varieties on CH_4 and N_2O emissions over two years under contrasting climate conditions like a 'warm and dry' season in 2013 and a normal season in 2014 and the reduction in the amount of irrigation water applied effectively reduce the CH_4 emissions regardless of the rice variety and climate condition. In contrast, N_2O emission depended more on fertilization and Standing Surface Water Depth (SSWD) than on rice variety. This study deals about the GHGs emissions from wetlands of Rwanda. The overall objective of this study is to find out the soil and weather parameters and to estimate GHGs emission from rice fields of Muvumba P-8 marshland. The specific objective is to estimate the Carbon dioxide (CO_2), Nitrous Oxide (N_2O) and Methane (CH_4) emission from the rice field at different time.

2. Methods

2.1 Estimation of Green Houses Gases from the rice field

An experiment was conducted in rice season to estimate the Carbon dioxide (CO_2), Nitrous Oxide(N_2O) and Methane (CH_4) emission from the rice fields of Muvumba P-8. It was conducted from February to June 2018. There were 9 plots of 8 m x 8m size used for the study. Gas emission was collected at 6 am, 9 am, 12 Noon and 3 pm. Totally 3 gas collection chambers were installed in the plots. Greenhouse gases emitted from the rice field were collected in the chambers. The chambers were closed and gas samples were collected from the chamber headspace at time intervals of 3 minutes among the three chambers. The gas was stored in a jar and sent to SLU laboratory, Uppsala, Sweden to measure the content of Carbon dioxide (CO_2), Nitrous Oxide(N_2O) and Methane(CH_4) using Gas Chromatography. The experiment was repeated for 4 times for each plot. The output from Gas chromatography is in mol-ppm and it was converted to µg m-2 h-1 as per Olive Tuyishime (2018). Flux was calculated from the concentration change over time using the equation stated below

GHG gas production in microgram/sq.m/hour (F_o) =

$$s\frac{V\,M\;\;273.16}{A\,Vm\;\;273.16+T}\;3600 \qquad \text{eq.(1)}$$

Where

F_0 = GHG gas production in at the time of chamber closure t_0 (µg m-2 h-1)

S = time derivative (slope) (ppm/sec) obtained from Gas Chromatography recording

V = chamber volume (m^3)

A = chamber area (m^2)

M = molecular mass of CO_2 and N_2O was 44 g mol-1, for CH4 it was 16 g mol-1

Vm = ideal gas mole volume (0.0224 m^3 mol-1)

T = chamber headspace temperature (°C)

Note: Vm includes the effect of pressure and temperature

Before sampling fans were installed, it was ensured that the top of the chambers must have the atmospheric air inside the chamber. The gases in the chamber were drawn away (so as to keep it vacuum) with a pump and immediately connected to a 25-ml vacuum glass container. Then the GHGs were collected into the vacuum glass container at different time intervals (at 6am, 9am, 12noon, 3pm and 6am). This collection was repeated for 4 times *i.e.,* 9 plots x 4 different times per plot x 4 replications giving 144 gas sample collections. The time taken to collect gas sample in a plot was 1 minute. The time interval between data collection from one plot to another plot was 3 minutes. The total time interval estimated to collect data from 9 plots will be 9 plots x (3 minutes + 1 minute) giving 36 minutes for one replication.

2.2 Computation of mean CO_2, N_2O and CH_4 collection from rice field

The results of the analysis from Gas Chromatography about the CO2, N_2O and CH_4 were in parts per million. It was converted into microgram/square meter/hour using a formula discussed in equation (1). The calculated CO_2, N_2O and CH_4 from the 9 plots for four replications were tabulated for further discussion and analysis.

2.3 Pattern of behavior of mean CO_2, N_2O and CH_4 gas emission in different time of day

The mean CO_2, N_2O and CH_4 gas emission for the 9 plots for 6 am, 9 am, 12 Noon and 3 pm were recorded in a graph by taking plots in x axis and the mean CO_2, N_2O and CH_4 gas emission in y axis in three different graphs. These graphs were discussed in detail for the pattern of behavior of mean CO_2, N_2O and CH_4 gas emission in different time of day.

2.4 Relationship between of soil temperature and emission of GHGs from the rice field.

A graph was prepared by taking time of the day (6am, 9 am, 12 noon and 3 pm) in x axis and the mean CH_4 production for the four time of the day in y axis to find out the relationship between the time of the day and mean CH_4 production. A second graph was prepared by taking time of the day (6am, 9 am, 12 noon and 3 pm) in x axis and the mean CO_2 production for the four time of the day in y axis to find out the relationship between the time of the day and mean CO_2 production. A third graph was prepared by taking time of the day (6am, 9 am, 12 noon and 3 pm) in x axis and the mean N_2O production for the four time of the day in y axis to find out the relationship between the time of the day and mean N_2O production.

3. Results and discussions

Data were collected from 9 plots in the rice field of Muvumba marshland about the GHGs emission. The gas samples were taken to Swedish Agricultural University laboratory for analyzing the quantity of emission of the gas. This study is mainly focusing on the estimation of Carbon dioxide (CO_2), Nitrous Oxide (N_2O) and Methane(CH_4).

3.1 Computation of mean CO_2 collection from rice field

The data collected from the gas chromatography was in ppm mol. It was converted into µg CO_2 m-2 h-1 using a particular formula as described in Chapter 3.The calculated CO_2 collection from the output of Gas Chromatography is given below.

Table 3.1 Calculated mean CO_2 collection from 9 plots with four replications in µg CO_2 m-2 h-1

Plot	6:00 AM	9:00 AM	12 Noon	3:00 PM	Mean	Std Deviation
P1	2187594	1624846	1703290	1448263	1740998	316256.7
P2	2118137	2019261	1975649	2496304	2152338	236932.3
P3	2022407	2001559	1818415	2304035	2036604	200462.4
P4	1598374	2209165	1752715	1910859	1867778	260908.1
P5	2479028	1848058	1866616	1646327	1960007	360107.6
P6	1781191	2330902	1333647	2088366	1883527	430094.6
P7	1981693	2057590	2133873	1928916	2025518	89483.7
P8	1840128	2345034	1737877	2209518	2033139	290299.2
P9	2008785	1693075	2128895	1588347	1854776	255598.4
Mean	2001926	2014388	1827886	1957882	1950521	271127
Std Deviation	253534.2	257912.6	245256.7	351150.1		

As per table 3.1, it was measured that the mean CO_2 gas emission for 6 am, 9 am, 12 Noon and 3 pm for 9 plots are 2001926, 2014388, 1827886 and 1957882 µg CO_2 m-2 h-1. It was found that the CO_2 gas emission was low at 9 am and 12 Noon. The maximum CO2 gas emission at 9 am is due to the fact that during night time rice plant takes more CO_2 and release the same due to ambient temperature rise at 9 am. The minimum CO_2 gas emission at 12 Noon is due to the fact that rice plant released all its CO_2 during morning time around 9 am and there was less CO_2 in the rice plant to release at 12 Noon. The standard deviation of CO_2 gas emission at 3 pm is very high in the order of 351150.1. Too much variation of CO_2 gas emission at 3 pm is due to the fact that the rice plant was exposed more time to sunshine from morning to 3 pm. As the ambient temperature is more then there is more variation of CO_2 gas emission at 3 pm. The CO_2 gas emission for the 9 plots for 6 am, 9 am, 12 Noon and 3 pm were recorded in a graph by taking plots in x axis and the CO_2 gas emission in y axis.

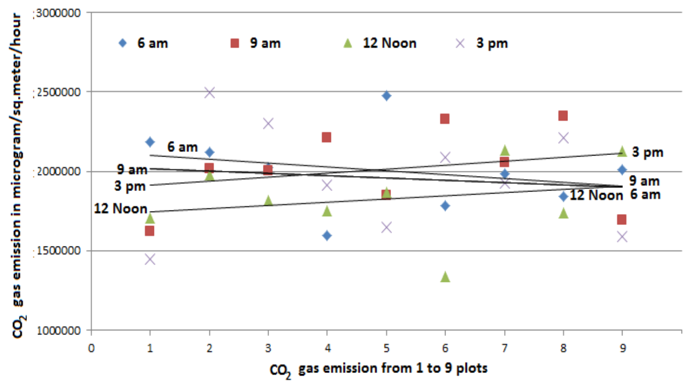

Figure 3. Trend line of CO_2 gas emission at 6 am, 9 am, 12 Noon and 3 pm for 9 plots

It was observed that CO_2 gas emission at 6 am starts high and the trend line is linearly decreasing from 2479028 to 1598374 µg CO_2 m-2 h-1. The mean CO_2 gas emission at 6 am was found to be 2001926 µg CO_2 m-2 h-1. The scatter diagram does not show any clear pattern of behavior. In order to study the CO_2 gas emission behavior in a better way, linear trend lines were drawn for 6 am, 9 am 12 noon and 3 pm for the 9 plots. CO_2 gas emission at 6 am was high in the beginning and linearly decreases from 2479028 to 1598374 µg m-2 h-1. The mean CO_2 gas emission at 6 am was found to be 2001926 µg m-2 h-1(Figure 3).

It was found that the CO_2 gas emission at 9 am starts high and the trend line is linearly decreasing from 2345034 to 1624846 µg m-2 h-1. The mean CO_2 gas emission at 9am was found to be 2014387.78 µg m-2 h-1. It was found that the trend line at 9 am is below the 6 am line. It means that the CO_2 gas emission is high at 6 am compared to 9 am at the staring. The minimum CO_2 gas emission at 6 am and 9 am are almost same in the trend line with a small difference of 26472 µg m-2 h-1. It was found that the trend line of CO_2 gas emission at 12 noon started with minimum gas emission, the trend line is increasing from minimum gas production to maximum gas production. It is an increasing linear line. It is opposite to that of the trend lines of 6 am and 9 am. The interesting feature is the three trend lines of 6 am, 9 am and 12 Noon are almost coinciding at the same point with negligible differences of gas production.

CO_2 gas emission at 3 pm starts with minimum gas emission, the trend line is increasing from minimum gas production to maximum gas production. It is an increasing linear line similar to trend line of 12 Noon. The interesting feature is the trend line of 12 Noon and 3 pm are almost parallel. It seems they are behaving similar gas production trends but the magnitude of gas production at 3 pm is higher than 12 Noon. The important conclusion from the study is that CO_2 gas emission at 6 am is higher and it is followed by 9 am. It was also found that CO_2 gas emission at 12 Noon is the lowest one due to the fact that all CO_2 gases from the rice field were emitted in the morning time itself. After 12 Noon, there was one more phase of increase of CO_2 gas emission from 12 noon to 3 pm.

3.2 Calculated mean CH_4 collection from 9 plots with four replications

The results of the analysis from Gas Chromatography about the CH_4 were in parts per million. It was converted into microgram/square meter/hour using a formula discussed in methodology. The data collected from the gas chromatography was in in ppm mol. The calculated CH_4 from the 9 plots for four replications are given below.

Table 3.2 Calculated mean CH_4 collection from 9 plots in µg CH_4 m-2 h-1

Plot	6:00 AM	9:00 AM	12 Noon	3:00 PM	Mean	Std Deviation
P1	2943.47	2465.75	2398.55	2106.59	2478.59	346.93
P2	2635.97	2471.47	2475.18	2534.46	2529.27	76.77
P3	2506.59	2516.05	2429.93	2433.87	2471.61	46.04
P4	2239.44	2573.71	2221.98	2272.75	2326.97	165.83
P5	2581.07	2230.83	2192.99	2038.75	2260.91	229.04
P6	2224.04	2601.20	2139.82	2408.09	2343.29	205.21
P7	2476.83	2529.05	2439.25	2385.51	2457.66	60.58
P8	2325.91	2592.99	2256.18	2397.22	2393.07	145.18
P9	2455.51	2421.43	2445.58	2275.62	2399.54	83.84
Mean	2487.65	2489.16	2333.27	2316.98	2406.77	151.05
Std Deviation	222.84	171.89	173.17	175.84		

As per table 3.2, it was found that the mean CH_4 gas emission for 6 am, 9 am, 12 Noon and 3 pm for 9 plots are 2487.65, 2489.16, 2333.27 and 2316.98 µg m-2 h-1. It was found that the CH_4gas emission is high at 9 am and the minimum is at 3 pm among the mean gas production. The maximum CH_4 gas emission at 9 am is due to the fact that during night time rice plant takes more CH_4 and release the same due to ambient temperature rise at 9 am. The minimum CH_4 gas emission at 3 pm is due to the fact that rice plant released all its CH_4 during day time around 9 am to 3 pm and there was less CH_4 in the rice plant to release at 3 pm. The standard deviation of CH_4 gas emission at 9 am is very less in the order of 171.89 µg m-2 h-1. Too less variation of CH_4 gas emission at 9 am is due to the fact that the rice plant was exposed less time to sunshine up to 9 am. As the ambient air is heated due to sunshine from 6 am to 3 pm, there is less CH_4 gas emission at 3 pm.

The CH_4 gas emission for the 9 plots for 6 am, 9 am, 12 Noon and 3 pm were recorded in a graph by taking plots in x axis and the CH_4 gas emission in y axis.

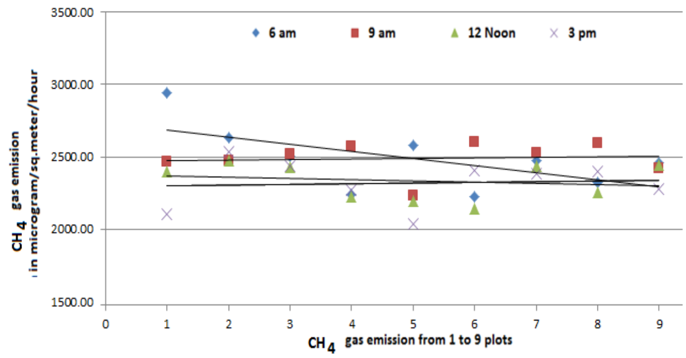

Figure 4 Trend line of CH_4 gas emission at 6 am, 9 am, 12 Noon and 3 pm for 9 plots

As per Figure 4, it was found that the CH_4 gas emission at 6 am starts high and the trend line is linearly decreasing from 2943.47 to 2224.04 µg m-2 h-1. The mean CH_4 gas emission at 6 am was 2487.65µg m-2 h-1. It was observed that the CH_4 gas emission at 9 am was almost a linear straight line without appreciable fluctuations in gas production from all the 9 plots. Hence, CH_4 gas emission is static irrespective of plots at 9 am(2489.16 µg m-2 h-1). The range varies from 2230.83 to 2601.2 µg m-2 h-1.

The trend line of CH_4 gas emission at 12 noon starts decreasing with the range of 2139.82 to 2475.18 µg m-2 h-1. Although a difference between the maximum and minimum gas emission of 335.36 µg m-2 h-1 was noticed among the plots, was not appreciable and hence the slope of the trend line is 0.15 or 15% only. The mean CH_4 gas emission was 2333.27µg m-2 h-1 among the 9 plots at 12 noon. CH_4 gas emission at 3 pm is almost a linear straight line without appreciable fluctuations in gas production from all the 9 plots. We concluded that the CH_4 gas production is constant irrespective of plots at 9 am. The mean CH_4 gas emission at 3 pm was 2316.98 µg m-2 h-1, ranging from 2038.75 to 2534.46 µg m-2 h-1. We conclude that CH_4 emission is similar in all plots at 9 am and 3 pm. CH_4 gas emission was decreasing at 6 am and 12 noon due to the complex digestive nature of organic matter within the soil and the random activities of the methanogenic bacteria present in the soil.

3.3 N_2O collection from plots

The results of the analysis from Gas Chromatography about the N_2O were in parts per million. It was converted into microgram/square meter/hour using a formula discussed in methodology. The calculated N_2O from the 9 plots for four replications are given below.

Table 3.3 Calculated mean N_2O collection from plots with four replications in µg N_2O m-2 h-1

Plot	6:00 AM	9:00 AM	12 Noon	3:00 PM	Mean	Std Deviation
P1	1105.16	939.82	1084.00	863.90	998.22	115.83
P2	1041.42	959.48	934.41	1039.20	993.63	54.87
P3	975.70	1052.20	1006.05	894.55	982.13	66.32
P4	904.08	929.64	917.78	857.41	902.23	31.65
P5	924.34	957.63	936.58	871.20	922.44	36.82
P6	855.76	1001.58	787.39	928.86	893.39	92.40
P7	1015.15	1039.08	914.13	968.23	984.15	55.18
P8	935.62	1047.05	970.69	903.13	964.12	61.78
P9	1073.13	1035.87	982.72	938.01	1007.43	59.32
Mean	981.15	995.82	948.19	918.28	960.86	63.80
Std Deviation	83.38	49.51	80.44	58.40		

As per table 3.3, the mean observed N_2O gas emission for 6 am, 9 am, 12 Noon and 3 pm for 9 plots was 981.15, 995.82, 948.19 and 918.28µg m-2 h-1 respectively. N_2O emission was high at 9 am and the minimum at 3 pm. The maximum N_2O gas emission at 9 am might be reasoned to the fact that during night time rice plant takes more $N_2O$and release the same due to ambient temperature rise at 9 am. The minimum N_2O gas emission at 3 pm might be attributed to the release of all N_2O from the rice plant during morning time around 9 am to 3 pm and there was less N_2O in the rice plant to release at 3 pm. The standard deviation of N_2O gas emission at 3 pm is very less in the order of 58.40 µg m-2 h-1. Less variation of N_2O gas emission at 3 pm is due to longer exposure of rice plant to sunshine from morning to 3 pm. As the ambient temperature is more then there is less N_2O gas emission at 3 pm. The N_2O gas emission for the 9 plots for 6 am, 9 am, 12 Noon and 3 pm were recorded in a graph by taking plots in x axis and the N_2O gas emission in y axis.

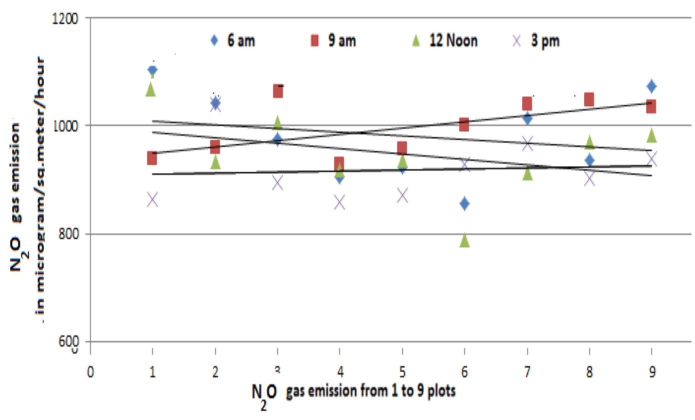

Figure 5. Trend line of N_2O gas emission at 6 am, 9 am, 12 Noon and 3 pm for 9 plots

N_2O gas emission at 6 am starts high and the trend line is linearly decreasing from 1105.16 to 857.41 µg m-2 h-1. The lowest N_2O gas emission was recorded at 12 noon with 787.39µg m-2 h-1. It was found that the N_2O gas emission at 9 am starts low and the trend line is linearly increasing from 929.64to 1052.20 µg m-2 h-1. The mean N_2O gas emission at 9am was found to be 995.82µg m-2 h-1. It was found that the trend line at 9 am is opposite to that of trend line of 6 am. It means that the N_2O gas emission is high at 6 am compared to 9 am at the staring. The relationship of N_2O gas emission at 6 am and 9 am are opposite because of inverse nature of gas emission. The N_2O gas emission for 6 am is decreasing and that at 9 am is increasing(Figure 5).

It was found that the N_2O gas emission at 12 noon starts high and the trend line is linearly decreasing from 1084.00 to 787.39 µg m-2 h-1. The lowest N_2O gas emission during the day time was found at 12 noon with 787.39µg m-2 h-1. It was found that the trend line of N_2O gas emission at 12 noon is decreasing from maximum to minimum gas production. It is a decreasing linear line. It is similar to that of the trend line of 6 am but opposite to that of 9 am. It was found that the N_2O gas emission at 3 pm starts with minimum gas production, the trend line is increasing from minimum gas production to maximum gas production. It is an increasing linear line similar to trend line of 9 am but the rate of change of increase is smaller compared to 9 am trend line. It was found that the gas emission at 6 am and 12 noon are behaving similarly with decreasing trend. It was also found that the gas emission at 9 am and 3pm are behaving similarly with increasing trend.

4. Conclusions

The study of estimation of GHG gases from the rice fields of Muvumba P-8 marshland gives several conclusions. CO_2 gas emission is maximum at 9 am and minimum is at 12 Noon. During night time rice plant takes more CO_2 and release the same due to ambient temperature rise at 9 am. The minimum CO_2 emission at 12 Noon is due to the fact that rice plant released all its CO_2 during morning time around 9 am and there was less CO_2 in the rice field to release at 12 Noon. Mean CO_2 gas emission among the experimental plots was 1950521 µg m-2 h-1. CO_2 emission at 12 Noon is the lowest one due to the fact that all CO_2 gases from the rice field were emitted in the morning time itself. After 12 Noon, there was one more phase of increase of CO_2 gas emission from 12 noon to 3 pm. **2.** The mean CH_4 gas emission at 6 am was 2487.65 µg m-2 h-1. CH_4 emission was similar irrespective of experimental plots at 9 am (2489.16 µg m-2 h-1) with a range of 2230.83 to 2601.2 µg m-2 h-1. CH_4 gas emission at 3 pm was 2316.98 µg m-2 h-1 (2038.75 to 2534.46 µg m-2 h-1). CH_4 emission decreased at 6 am and 12 noon due to the complex digestive nature of organic matter within the soil and the random activities of the methanogenic bacteria present in the soil. **3.** N_2O gas emission at 6 am, 9 am, 12 Noon and 3 pm for the plots were 981.15, 995.82, 948.19 and 918.28µg m-2 h-1. Emission is high at 9 am and the minimum is at 3 pm. The mean of N_2O gas emission at 6 am, 9 am, 12 noon and 3 pm of all the experimental plots was found to be 960.86 μg m-2 h-1. **4.** Factors like change in water table with time in all the plots, fluctuation in soil temperatures and difference in soil, and its composition among the plots, availability of nitrogenous fertilizers in the soil, soil microbiological activities of methanogenic bacteria and organic matter content contributed to the variations in emission levels.

5. Acknowledgement

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